COAL AND IRON IN SOUTHERN OHIO.

THE

# MINERAL RESOURCES

OF

# THE HOCKING VALLEY:

BEING AN ACCOUNT OF

ITS COALS, IRON-ORES,

BLAST-FURNACES, AND RAILROADS.

WITH A MAP.

BY

T. STERRY HUNT, LL.D.

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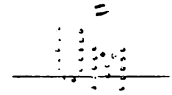

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# PREFACE.

It was in 1874, that after having spent some time in examining the coal-measures of the Hocking Valley, in south-eastern Ohio, and having collected from public and from private sources what was then known of the region, I published an account of it, long since out of print.* At that date the Geological Survey of the State was in progress; but of the final report only volume I. had appeared, though volume II. was published in the same year. In 1878, appeared volume III., including three chapters, one each by Profs. Read, Andrews and Orton, on the region in question, which added much to our knowledge of its geology and mineral resources.



Since that time, despite the financial depression of 1874–78, considerable activity has prevailed in the Hocking Valley, which has attracted a large amount of capital. New railroads, opening up the region, have been built, and new coal-mines opened, while the shipments of coal therefrom have much more than doubled, and promise great increase for 1881. Moreover, a new industry, that of smelting the native iron-ores with the raw coal of the region, has been established, and within the period named thirteen blast-furnaces have been erected and put in successful operation, besides which, two more of the largest size are now in process of construction.

Having all these facts in view, and moreover, having during the years 1879 and 1880 made numerous visits to the region, and spent much time in the examination of various parts of it, I have in the following pages attempted to give a summary of the geology of the Hocking Valley, as far as now known, together with an account of its resources in coal and

* The Hocking Valley Coal-Field and Iron-Ores, with Notices of Furnace-Coals and Iron-Smelting, followed by a View of the Coal Trade of the West. By T. Sterry Hunt, LL. D., pp. vi, 78, with two maps. Salem, Mass.: Naturalists' Agency, 1874. (This was published in May, 1874.)

iron-ores, and a history of its blast-furnaces and iron-smelting, with a brief notice of its railway connections. In carrying out this plan I have made free use of the volumes of the Geological Survey, especially that of 1870, containing Dr. Wormley's report on the chemical composition of coals and iron-ores, and also volume III. of the final report, already mentioned as published in 1878; supplementing the information thus obtained with the results of my own examinations, and with facts gathered from a great variety of other sources. I have here to thank Dr. J. S. Newberry, Director of the Geological Survey of Ohio, for information, and for many personal favors, and at the same time to express my great obligations to the late lamented Prof. E. B. Andrews, of Lancaster, Ohio; to President Edward Orton, of the State University at Columbus, Ohio; and to Prof. M. C. Read, of Hudson, Ohio, for much valuable information, always cheerfully given; as also to the Rev. J. P. Weethee, of Millfield, Trimble, Ohio, whose familiarity with the geology of the Sunday Creek Valley has enabled him to throw light on many obscure points. To Col. I. B. Riley, C. E., the superintendent of the furnaces now being erected by the Buchtel Iron Co., at Floodwood, Ohio; to the officers of the Hocking Iron Co., both in Ohio and in Boston, and especially to Mr. Gilbert Attwood, secretary, and Mr. John B. Pearse, consulting engineer of the two companies just named, both of Boston; to Mr. J. M. Welch, of Athens, Ohio; to Mr. H. T. Niles, of Aurora, Ohio; to Dr. Rannels, of McArthur; to Mr. Buchtel, president of the Akron Iron Co.; to Mr. Shields, president of the Licking Iron Co.; to Gen. J. C. Hamilton, of Shawnée; to Mr. Walter Crafts, of Columbus, president of the Crafts Iron Co.; and especially to Gen. Samuel Thomas, also of Columbus, president of the Columbus Rolling Mill Co. and of the Thomas Iron Co., a pioneer in the development of this mineral region, I am indebted for much information and many courtesies.

I have also to express my obligations to Mr. Walston H. Brown, of New York, one of the directors of the Ohio Central R. R. Co., for data concerning that road; and to acknowledge my great indebtedness to Mr. W. H. Jennings, of Columbus, chief engineer of the Columbus and Hocking Valley R. R., for notes of surveys, levels, and other observations, which he has with great liberality placed at my service. To give the names of explorers and others who, in the field and otherwise, have

aided me would make too long a list; but I may mention, especially, Mr. Jos. W. Jones, of Trimble, Ohio, Mr. Daniel Fulton, of Dover, Mr. Falloon, of Athens, and Mr. J. C. Parker and Mr. J. Edington, of Nelsonville.

As to the geology of the region, some uncertainty exists with regard to the coals above the Great Vein, and I have, on page 22 and succeeding pages, referred to the difficulties attending their study. Farther researches may not improbably lead to a revision of some of the opinions expressed by myself, and by others, as to the horizon of certain of these coals, especially in the valleys of Monday Creek and Sunday Creek. I shall at all times be obliged for new observations, or for corrections of errors in the account of the region here given, which I cannot hope to have wholly avoided.

In discussing the questions of coal-mining and iron-smelting, I have called attention to some points connected with these subjects, which, although familiar to technical students, will, it is hoped, not be without value to others who may be interested in the region. With the same end in view, I have added some statistics with regard to coal and iron-ores and the iron and steel manufactures of the country. For many of these I am indebted to Mr. Fred. E. Saward's valuable manual, entitled *The Coal Trade*, for 1880, and to the excellent annual report for 1880, of Mr. James M. Swank, secretary to the American Iron and Steel Association. Readers will find that pages 73–86, including coal-analyses and many details connected with coal, are copied, with some additions and revisions, from my little treatise of 1874. Some notes with regard to clays and salt-wells, I have reserved for an Appendix, where also will be found a detailed inquiry into the dip of the strata, as deduced from observations on the Great Vein in different parts of the coal-field.

The accompanying map has been prepared with great care by Mr. W. H. Jennings, chief engineer of the C. & H. V. R. R., and will be found to give a correct view of the region, with its completed and projected railroads and its blast-furnaces.

T. S. H.

MONTREAL, CANADA, Jan. 25, 1881.

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APPENDIX.

# THE HOCKING VALLEY COAL-FIELD.

§ 1. The great Appalachian coal-basin, which includes the coal-bearing strata of Pennsylvania, Maryland, Ohio, West Virginia, eastern Kentucky, eastern Tennessee, Georgia, and Alabama, has a total area of about 58,000 square miles, of which about 10,000, constituting the north-west portion, are included in south-eastern Ohio. A certain bed of coal there assumes an exceptional thickness and value in a part of the region drained by the Hocking River and its tributaries, and the area of about 250 square miles characterized by it has thus come to be known as the Hocking Valley coal-field, beyond the limits of which the coal-seam in question is either absent, or no longer possesses its valuable qualities. It is proposed in the following pages to give a brief account of this coal-field, of its resources in coal and iron, its industrial development, and its commercial relations.

§ 2. The strata of the great Appalachian coal-basin are, in accordance with the nomenclature of the First Geological Survey of Pennsylvania, generally divided into a Lower and an Upper Series, the well-known and important coal-bed

called the Pittsburg seam being regarded as the base of the Upper Series. The thickness of the members of the Lower Series, in which the Hocking Valley coal-field is included, is subject to many local variations; but their aggregate in southern Ohio is estimated at from 700 to nearly 900 feet. We have no evidence that the lower beds of the series, which are exposed with a slight eastward dip along the western border of the basin, pass with unchanged thickness beneath the higher beds that are met with farther to the eastward. On the contrary, it is pretty certain that the coal-beds of the series grew, as has been well said by Prof. Orton, in a marginal marsh, not very many miles in breadth, and thus had their natural limits in this region both to the eastward and the westward.

§ 3. The Lower Series of the coal-measures in this region may, for our present purposes, be conveniently divided into two portions; namely, those below and those above a well-defined formation of limestone, which, from its association with an important deposit of iron-ore, has been called the Ferriferous limestone. This iron-bearing limestone, which has also been designated in various localities as the Hanging-Rock, the Putnam-Hill, and the Gray limestone, constitutes a marked horizon in the Lower Coal-measures of Ohio, and is separated by an interval, varying in different localities from 250 to 350 feet, from the base of the series. Beneath this limestone are found several coal-seams designated in the notation adopted by Dr. Newberry in the geological survey of Ohio by the numbers I, II, III, and IV; besides two seams called III*a* and III*b*, intercalated between III and IV. This inferior division of the Lower Series also includes two bands of limestone, and several important horizons of iron-ore.

§ 4. The Ferriferous limestone lies but a few feet above Coal IV, and about forty feet below Coal VI, which is the so-called Great Vein that gives character to the Hocking

Valley Coal-field. This limestone may therefore be conveniently and properly taken as the starting-point in the succession of strata in the field. The following general section shows the principal beds of coal and limestone from the Ferriferous limestone to the Pittsburg coal; the numbers given to the coal-seams being those employed by Dr. Newberry, while the figures prefixed show the approximate average heights in feet over this limestone, taken as a base. These figures, however, are subject to considerable variations from the greater or less thickness of the sandstones and shales which intervene between the limestones and coals. Thus, the interval between the Shawnee and Cambridge limestones in the Hocking Valley, varies from 100 to 110 feet, and farther south rises to 120 and 150 feet; while that between the last and the Ames limestone ranges, in the Hocking Valley field, from eighty-five to 120, and to the southward, rises to 140 feet. In like manner, the interval between Coals VI and VII, which in the section is given at ninety feet, varies from ninety to 100 feet, and in some localities may be greater or less than these distances; while the interval between Coal VI and the underlying Baird ore, which we have given as fifty feet, varies from thirty to fifty feet in the Hocking Valley, and farther south becomes sixty feet or more. From these variations it results that different measurements give an interval of from 440 to 500 feet between the Ferriferous limestone and the Pittsburg coal.

The iron-ores of the series, and also some additional limestones of secondary importance, will be noticed farther on. The section here given requires modifications for the south-east part of the field; that is to say, for the lower Sunday Creek valley.

§ 5. The inclination of the strata in the region under consideration varies from fifteen to thirty feet to the mile, in a direction east-south-east, and the Pittsburg seam, which forms the base of the Upper Coal Series, is only met with

east of the limits of the Hocking Valley coal-field, though the Ames limestone appears on many of its higher lands.

*Section of Upper Portion of the Lower Coal-Measures.*

| Feet. | |
|---|---|
| 480 | Coal VIII, or Pittsburg seam. |
| 350 | Ames limestone. |
| 230 | Cambridge limestone. |
| 180 | Coal VII*a*. |
| 140 | Coal VII. |
| 120 | Shawnee limestone. |
| 100 | Coal VI*b*. |
| 80 | Coal VI*a*. |
| 50 | Coal VI or Great Vein. |
| 10 | Coal V. |
| 0 | Gray or Ferriferous limestone and Baird ore. |

§ 6. It will be observed that the upper part of the above section is without coal-seams, and hence it has been the custom to speak of these upper beds of the Lower Coal Series as the Lower Barren Measures, in contradistinction to the Lower Productive Measures which underlie them; (the Upper Series being in like manner divided into Barren Measures above and Productive Measures below). The summit of the so-called Lower Productive Measures in Pennsylvania is what is known as the Upper Freeport coal, the precise equivalent of which in the present region is disputed, but is regarded by Orton as VII*a*, the 300 feet of strata overlying which are Barren Measures in south-eastern Ohio.

§ 7. We may now proceed to notice in succession the thickness and the mineral characters of the several beds named in our section, beginning with the coals. In this task free use will be made of the published reports of the geological survey of Ohio, which includes the work of the late Prof. E. B. Andrews, of Prof. M. C. Read, and of Prof. Edward Orton, now President of the Ohio State University, each of whom, in addition to observations in previous volumes, has

furnished a chapter on the present region to volume III. of the Geological Survey of Ohio, published in 1878. To the above sources of information are added my own observations during some years, now extending over the larger part of the field. Some differences of opinion as to the identification and equivalence of coal-seams have arisen among the geologists just named, in the discussion of which I have availed myself of comparison and criticism.

§ 8. Coal V. This bed, which is very constant in its place from twenty to thirty feet below Coal VI, is supposed by Orton to be the equivalent of the Newcastle seam which is worked to considerable extent near Ironton in southern Ohio. It is not mined in the Hocking Valley field, where it has, however, a thickness of two or three feet, and is said to yield a good coking coal, which is well fitted for blacksmithing, and was at an early day mined to some extent for this purpose near Nelsonville. From its proximity to Coal VI, this lower seam has been neglected.

§ 9. Coal VI. This, which is regarded by Newberry as the equivalent of the Upper Freeport, and by Orton as corresponding to the Kittaning Middle coal of Pennsylvania, appears in the region under consideration as a dry-burning or non-coking coal of superior quality, with a thickness varying from six feet (rarely less) to twelve feet and upwards, and it is to the area in which this development occurs that the name of the Hocking Valley coal-field is given. It is this seam which furnishes the fuel for the iron-furnaces of the region, and which is mined and exported under the various names of the Hocking Valley, Straitsville, Shawnee, Monday Creek, Haydensville, and Nelsonville coal. The seam itself is commonly known in the region as the Great Vein of coal.

§ 10. This coal-seam, with the characteristics already named, is seen along the western outcrop of the Lower Coal-measures from the township of Brown in the north-

east corner of Vinton County, through the eastern part of Hocking County into Salt Lick and Monroe townships in Perry County, where it attains its greatest thickness of twelve and thirteen feet, but beyond this point rapidly diminishes in thickness, its quality at the same time becoming inferior. The surface in these counties presents considerable elevations, known as the Hocking Hills, and the Great Vein, rising with the gentle inclination of the strata (from fifteen to thirty feet to the mile) to the N. N. W., appears in the hills in parts of the townships of Starr, Green, and Monday Creek, which lie along the north-west border of the line of outcrop. In the intermediate valleys, however, the coal has been removed by erosion, and this is also true to some extent of the valleys in the townships of York, Ward and Salt Lick, lying to the east of those just named, where the Great Vein is seen in the valleys of the stream known as Monday Creek, and its tributary, Snow Fork, in the eastern part of York and Ward. Immediately to the eastward of the townships last named the Great Vein disappears beneath the hills which lie in Trimble and Dover between the valley of Snow Fork and the lower part of Monday Creek on the west, and the Sunday Creek valley on the east. Its presence underlying the portions of Trimble and Dover thus defined, has been proved by numerous borings. To the eastward of the Sunday Creek valley it is not known, and though found in the north-west part of the township of Athens, it appears, from a shaft near the town of that name, to be irregular and reduced in thickness. It is probable, for many reasons, that the Great Vein thins out to the south-east of the limits already indicated.

§ 11. In estimating the area of the Hocking Valley Coal-field, or rather that within which the Great Vein is found with a thickness of five feet or upwards, it must be remembered that except in those parts to the south-east in which it lies below water-level, more or less of the coal has been re-

moved in the cutting-out of the valleys. Without a careful topographical survey of the region, any attempt to determine the amount thus cut away must be but an approximation. We may however fairly take the portions underlaid by the Great Vein in the south-eastern parts of Starr, Green, and Monday Creek to be equivalent to those removed by erosion from the townships of Brown, York, Ward, Salt Lick, Coal (which has lately been constituted from the southern third of Salt Lick), Monroe, and the southern quarter of the small township of Pleasant, which is, as it were, cut out from the northern parts of Salt Lick and Monroe. To these we may add the whole of the township of Trimble, the west half of Dover, and the north-west quarter of Athens. Nothing is as yet known of its existence in the remainder of this township, or in the south-eastern part of Waterloo. If, as above suggested, we reckon as entire the six full-sized townships of Brown, York, Ward, Salt Lick, Monroe, and Trimble (including in them Coal and part of Pleasant), we have 216 square miles. If, now, to these we add twenty-four miles for the western two-thirds of Dover, nine miles for the north-west quarter of Athens, and twenty-seven miles for the northern and western three-fourths of Waterloo, we shall have a total of 276 square miles, or about 176,000 acres. From this, however, considerable deductions must be made on account of irregularities which, during the deposition of the coal-measures, affected the Great Vein over certain portions of the field to be mentioned farther on.

§ 12. As regards Coal VI to the north of the area already defined, it is seen north of Monroe in Bearfield, and again in the hills in sections 16 and 30 of Pike, in each case with a thickness of about four feet; while in the south-east corner of Jackson its volume is still farther diminished, the quality of the coal in these localities being also inferior. A thinning of the Great Vein is also to be observed in the north-west corner of Salt Lick township, though the coal is

mined at McCuneville in section 8, both for salt-making and for exportation, and northward along the railroad as far as the Bristol Tunnel, but is said to be less dry-burning than farther south. To the north and west of Shawnee, where the Great Vein first appears, it lies near the tops of the hills, and from 100 to 150 feet above the bottom of valleys. Its thickness here is from five to seven feet, but it augments to the south-east, and near Shawnee and Old and New Straitsville, where it is extensively mined, it becomes ten and eleven feet in thickness, and lies from thirty to fifty feet above the valleys. Near Shawnee, on the east, it is partially affected by an ancient erosion, which has removed a part of the upper bench of the coal-seam; but at the town of Shawnee, near the centre of Salt Lick, it has already a thickness of nine and ten feet, and is excellent in quality. In like manner, we find the Great Vein in the north-west corner of Pleasant, with a thickness of only five feet, but following southward down the valley of the Moxahala, it soon increases to six and seven feet, and in the south-eastern corner of the township rises to eleven and twelve feet in thickness.

§ 13. Proceeding south-westward along the western border of the coal-field, we find the Great Vein measuring only four feet in section 2 of Monday Creek. It is seen with a thickness of seven feet in the south-east corner of the same township, and again in the south-east corner of Green, at Haydensville, where it is extensively mined, and measures 6′ 4″. A seam of a little over four feet in section 35 of Starr is regarded by Orton as probably the representative of the Great Vein. This, in the south-east quarter of Starr, in section 7, measures 6′ 6″, while in recent openings in section 8, it is said to be 6′ 6″, and in section 13, not less than 9′ 4″ in thickness. Proceeding thence south-west, it is seen in section 23 of Brown, in the valley of Two-mile Run, with a thickness of 6′ 8″, or more, and a little farther south,

in a boring for salt, in fraction 32 of Brown, on Little Sand Creek, was found at a depth of sixty-five feet, it is said, with a thickness of seven feet. What is supposed to be the same seam of coal has recently been found at a depth of twenty-seven feet in a shaft near Hope Station, in Brown, on the Marietta and Cincinnati Railroad, where, however, its thickness was only 4′ 8″.

§ 14. Recent observations, for which I am indebted to J. M. Welch, Esq., of Athens, Ohio, throw farther light on the development of the Great Vein in this vicinity. An outcrop, apparently of this coal, is seen in the channel of Raccoon Creek, in section 19 of Brown, not far from Hope Station, but at the time of my visits has always been partially concealed by water. During the drought of 1879, as I am informed by Mr. Welch, the coal-seam was fully exposed, and found to have a thickness of seven feet. It was also seen elsewhere along the same valley as far as the north-west corner of the township of Knox, where it showed the same thickness.

§ 15. Taking next the townships to the east of Green, Starr, and Brown, we note that in Ward, which bounds Green on the east, the Great Vein has, in the north-west corner, a thickness of six feet, which in section 24 rises to ten and a half feet, and in the outcrops along Snow Fork, in the eastern part of the township, varies from seven to nine and ten feet. In the north-west part of York, where the Great Vein is extensively mined at Lick Run, and about Nelsonville, its thickness is about 6′ 6″, and farther south, where it is exposed in the valley of Spring Branch, in section 32, it has the same measure, while near Bessemer, in the north-east corner of the township, it attains 9′ 6″. At Floodwood, in section 9, where Coal VI is mined, it is reduced at one place to 5′ 2″, but a little farther on in the drift rises to 6′ 2″; while less than two miles to the north-east, in section 4 of York, it is seen on the other side of the Hocking River with a

thickness of nine feet in section 4, and eight feet in section 3, where also the coal has been mined to a considerable extent by drifting.

§ 16. There are met with in Ward certain irregularities of the Great Vein, which are thus described by Prof. Read:

"Along the Snow Fork there is considerable evidence of ancient erosion, the shales having been removed and a sandstone roof covering the remaining coal. The coal is more reduced in thickness by this cause in the northern part of Ward than elsewhere; but at none of the outcrops where this erosion is shown, have drifts been carried into the hill far enough to determine the extent of the disturbance. At Ogden [Helen] furnace, however, in section 2 of Ward, an opening is made under the sandstone, which in a short distance rises above the coal, giving the latter a shale roof unevenly bedded and still showing the results of disturbance. The coal, which contained much sulphur under the sandstone, is found greatly to improve in character and increase in thickness. In some localities to the north of this, the coal is reduced to a few feet; and in all places where the sandstone comes down on the coal there is a liability of the coal being suddenly reduced in thickness, so as to be of little or no value. In all such cases entries should be driven into the undisturbed coal, or borings made in the hill to the horizon of the coal, and its thickness and quality determined before large expenditures are made."

§ 17. Another example cited by Prof. Read is as follows: "In the north-west quarter of section 17 of Ward, on the middle branch of Snow Fork, the coal is five feet ten inches thick, and of good quality; but east of this an outcrop was observed only one and a half feet thick, of sulphury coal, with heavy sand-rock above. Passing over the hills from this point towards Carbon Hill, the shales come in above the coal, which assumes its normal thickness and character." Similar disturbances have been noticed in York.

Thus, about a mile below the mouth of Meeker's Run, in a railroad-cutting, the upper part of the Great Vein is seen to be replaced by sandstone. These disturbances, however, so far as observation goes, are very local, and there is generally a good body of shale overlying the Great Vein throughout in both Ward and York.

With the exceptions above noted, it may be said that the Great Vein extends through Ward in a sheet varying from six to eleven feet in thickness, which is continuous save where cut out by the valleys which expose it, and it is not till we reach the eastern border of the township that the Coal VI sinks below water-level on the east side of Snow Fork. The same remarks hold good for York, except for its south-east portion, the last appearance of the Great Vein above the surface being about the mouths of Floodwood and Monday Creeks.

§ 18. In Waterloo, borings for oil in 1873 are said to have shown the Great Vein in section 17, near the centre of the township, at a depth of seventy-six feet, and farther east, in section 4, at a depth of 108 feet, in both cases with a thickness of six feet; while in section 12, on Hamley's Run, in the north-east corner of the township, it was found with a thickness of seven feet in a boring at a depth of sixty-four feet from the surface. Another boring in the south-west part of the township, in section 32, made in 1873, showed, according to Mr. Welch, at a depth of seventy feet, a seam, supposed to be the Great Vein, about six feet in thickness.

§ 19. It has been by some supposed that Coal VI is represented in the western part of Waterloo by the seam, generally from three to four feet in thickness, which is mined at Carbondale, at Mineral City, and at King's Switch, between the last and Moonville station, on the M. & C. R. R., but many observations lead to the conclusion this is one of the upper seams, and that the Great Vein lies below it. Prof. M. C. Read, in discussing the question of the

Carbondale coal, says, (Geological Survey of Ohio, vol. III., p. 697) :—

"Following down the valley from an outcrop near the south line of Starr, towards the coal-road leading to Carbondale, the Great Vein coal is seen to pass beneath the surface, and another coal fifty feet higher up, with a sand-rock a little above it, approaches the bottom of the valley. This sand-rock, and rude openings into the coal below, can be traced continuously around the hill to the east, and up the coal-railroad to Carbondale, making the identification of the coal above the last and that mined at Carbondale quite positive. So that if the coal which plunges beneath the valley west of Carbondale Hill is the Great Vein, this coal is certainly about fifty feet below the Carbondale coal, and of this fact I have very little doubt."

§ 20. It is reported that a lower seam of coal, measuring six feet, was found some years since in sinking for petroleum in the north-west corner of Waterloo. Borings in the interest of the coal proprietors have also been made, within the past few years, both at Carbondale and at Mineral City, but the results have not been made public, though I am informed by Mr. Peter Bechler of Carbondale that the Great Vein was met with below the Carbondale seam. A boring at King's Switch is said to have given similar results, and led to an attempt to shaft at that point for the Great Vein; but after sinking some thirty feet the work was abandoned, according to Mr. Bechler, for financial reasons. A thin intermediate seam was said to have been found in these borings which, as will be seen, confirm the observation made in section 32 of Waterloo, already noticed. The subject of the Carbondale coal and its probable position in the series will be considered farther on in treating of the upper coal-seams of the region.

§ 21. Passing now to Monroe, in the eastern range of townships in this coal-field, we find, in its north-west quarter, the

Great Vein exposed in the valleys, where it is seen in sections 7, 8, 9, and 18, measuring from eleven to thirteen feet. In the eastern part of this township it is found below the surface of the country, and here, as elsewhere along the Sunday Creek valley, numerous borings have been made for the purpose of determining its presence and thickness. In section 15, near Ferrara, the Great Vein was found at a depth of twenty-nine feet, with a thickness of 11′ 6″ feet; in section 23 at fifty-three feet, measuring 10′ 10″ feet; and in section 27 at sixty feet, measuring 9′ 6″ feet.

§ 22. Recent explorations in southern Monroe, and the adjacent parts of Salt Lick and Trimble, disclose a great irregularity of this coal-seam over a considerable area, which we cannot better describe than by quoting the statement given by Prof. Read, in vol. III. of the Geological Survey of Ohio, pp. 661–663.

"The Upper Sunday Creek region was separated from the rest of the Great Vein coal-field by a formidable barrier; namely, the bed of an ancient water-course which flowed through the old Carboniferous marshes in the ages immediately succeeding the subsidence which covered the Great Vein with argillaceous mud, now consolidated into shale. This stream came from the north, along a line midway between Buckingham and Shawnee, its precise location being in some places yet undetermined, but passing under Priest's Branch and along the valley, where is now the little village of Hemlock [in the south-east corner of section 24 of Salt Lick], and trending eastward, it followed nearly the line which now separates Perry and Athens counties. It cut away the shales above the Great Vein, and in places the whole thickness of the coal. In others it left a part of the coal, varying from a few inches up to the normal thickness, and gradually filled up the excavation with coarse material, now consolidated into sand-rock. This channel invaded the eastern part of the Newark Coal Company's property at Shawnee, but

left the greater part of the coal undisturbed. It thinned down that on the western part of the Carbon Hill property in the Moxahala region; left a thin body of coal at the point now worked at Hemlock, and a little to the east of this probably cut it all away."

§ 23. "An expensive experiment has determined more accurately its course and extent after striking the south line of Salt Lick township. Borings have been made through the horizon of this coal at the following named places, and with the following disclosures:"

"In section 36 of Salt Lick, at the south-west corner, the coal is 35 feet from the surface, and $2\frac{4}{12}$ feet thick; near the south-east corner it is, at the same depth, $2\frac{1}{2}$ feet thick. Near the centre of section 31 of Monroe, it is entirely wanting; at the south-east corner of the same section the first coal struck was six inches thick, and is found $64\frac{2}{12}$ feet from the surface, and covered with 42 feet 6 inches of sand-rock, which occupies the place of the Great Vein; the ancient channel here extending some 25 feet below this coal, and cutting away the upper part of the Lower Moxahala coal [No. V]. In the north-west corner of section 36 of Trimble, the coal is 37 feet below the surface, and one foot thick. A little north of the centre of section 29 of Monroe, it is 41 feet below the surface and $3\frac{1}{2}$ thick, and covered with 15 feet of sand-rock. North-west of the centre of section 28 of Monroe, it is 74 feet from the surface and three feet thick; south-east of the centre of the same section, it is 75 feet from the surface, and four inches thick. Near the south-west corner of section 33 of Monroe, it is 51 feet below the surface, six feet six inches thick, and covered with 33 feet of sand-rock; south-east of the centre of the same section it is 71 feet below the surface, and three feet thick. North-west of the centre of section 26, it is 74 feet 6 inches from the surface, and $9\frac{1}{2}$ feet thick. In the north-west

corner of section 23, it is 50 feet from the surface, and 11 feet thick. In the southern part of section 24, it is 91 feet 10 inches from the surface, and one foot thick."

§ 24. In the north-west corner of section 36 of Monroe the Norris coal [VI*b*] is 41½ feet from the surface, and 4½ feet thick. Below this, a boring disclosed a thickness of not less than 108 feet, consisting of shales, with a bed of nine feet of white limestone 67 feet below,— but no coal, the Great Vein and also Coal V being absent. This is in the south-east section of Monroe, the southern boundary of the eastern part of which section is the north-west corner of the township of Homer, in Morgan County. Near the centre of the north-west section of this township, and consequently about a mile east from the centre of section 6 of Trimble, a boring was carried to a depth of 155 feet, without encountering a single seam of coal, the strata consisting of shales, with more or less iron ore, and two or three layers of sand-rock, and, at the base, 16 feet of limestone.

§ 25. The absence of coal, and at the same time the presence of heavy limestones in these eastern borings suggests, as well remarked by Prof. Read, the probability of an area of open water at the time of the deposit of coal to the west, into which the ancient water-course, whose channel we have partially indicated, emptied. The carefully prepared charts of Mr. Nichols, compiled from levellings throughout this territory, lead Prof. Read to conclude that along the region thus eroded the Great Vein was never deposited in full force, but was originally thin, and in some parts wanting altogether, on account of a former local elevation of the surface. With this exception, and the smaller disturbances already mentioned as occurring in parts of Ward and York, (§§ 16, 17), he remarks: "The Great Vein is remarkably persistent, changing very gradually both in character and

thickness. North-west and south of this territory it is known to be a regular deposit, from eleven to thirteen feet in thickness, the line of maximum development passing north and south through the western parts of Monroe and Trimble, and cutting across the east and west belt which has been shown to be deprived of its coal."

§ 26. Passing southward into Trimble, we have already noticed that along the valley of the Snow Fork,—which for almost the whole distance runs near the line between Ward on the west and Trimble on the east,—the Great Vein appears with a thickness of from 9 to 10 feet, passing at once, however, beneath the hills of Trimble. In this township, except along the valley just named, where the Great Vein is seen in section 31, with a thickness of ten feet, and on the confines of 32, 33, and 34, measuring from nine to eleven feet, the coal is only found by sinking. In this region borings have been made along Green's Run and Bayley's Run, showing the existence of the Great Vein, with thicknesses of seven, eight, and ten feet, at depths of from 80 to 90 feet below the surface, in the lower part of the valleys of these tributaries of Sunday Creek. I have before me notes of not less than eleven such borings in Trimble, of which one is in section 6, in the north-east corner of the township, showing 8 feet of coal, and one near the south-east corner in section 7, where $8\frac{4}{12}$ feet are found at a depth of 84 feet in the valley of Sunday Creek. I have, in addition, the record of a trial-shaft sunk near the centre of the township, on Mud Fork, in the south-east part of fraction 36 of Trimble, where the Great Vein, with a thickness of 12 feet, was found 93 feet from the surface. We shall again have occasion to refer to this trial-shaft.

§ 27. Passing further southward into Dover, we notice that the Great Vein is here wholly below water-level. It has been shown that in the bordering sections, 3 and 4 of

York, the Great Vein has a thickness of eight and nine feet, and near the line of section 32 of Dover has been mined at a depth of 50 feet, where also the coal was found to be nine feet thick. Near the mouth of Hamley's Run, in the south-west corner of Dover, the coal is mined to a considerable extent through a shaft 69 feet deep. The vein is here eight feet thick, but the upper two feet are not extracted. At Salina, in the south-west section of Dover, are several salt-wells, which have been sunk to a depth of 600 feet. From the record of one of these, it appears that the coal, with a thickness of six feet, was met with at a depth of 98 feet, while another seam, corresponding to Coal V, and two feet thick, was found 33 feet lower. The coal of the Great Vein is mined by shafts, both here and at Chauncey, near by, in section 20, and is used as a fuel for the manufacture of salt from brines. The presence of the coal, with thicknesses of 7 and 6½ feet, is also indicated in section 22 and the adjoining fraction, 11, near the centre of the township. Nothing however is known of it in the eastern part of Dover.

§ 28. In the township of Athens, and near the town of that name, the coal of the Great Vein was reached some years since by a shaft at 200 feet, but the seam was found to be irregular, though in parts 5½ feet in thickness, and its working was abandoned. In a boring for salt, three miles farther to the west, it is said to have been found at a depth of 140 feet, and also in another boring two miles to the north, in both cases with a thickness of six feet. In the southern and eastern parts of Athens township, as in the eastern part of Dover, nothing is known of the Great Vein, which has not been sought for. The thinning and irregularity which it is said to have exhibited near the town of Athens may very probably indicate the running-out of Coal VI to the south and east.

§ 29. We have thus brought together the facts, so far as known, with regard to the distribution and the thickness of the Coal VI or Great Vein within the Hocking Valley coal-field, and may next proceed to notice the higher coal-beds of the field, already indicated in our section on page 4.

The relations of these higher coals, and their accompanying ores and limestones in the western part of the field, are shown in a section given by Orton, of the strata as seen in a hill on the land of John L. Gill, on Meeker's Run, south of Nelsonville, and near the centre of the township of York. Of this, Orton remarks: "It is a thoroughly representative section, embracing every valuable element but one that is due in a vertical range of 200 feet in the very heart of the Lower Coal-Measures. This single exception is the Baird ore, with its accompanying limestone, which is not to be recognized in its proper place in the series, as far as shown. The section is unusually complete, the openings being made so frequent and so extended, that it is scarcely an exaggeration to say that the hill from which it was taken is 'faced' from top to bottom. The intervals, in almost all cases, are those usually found in this part of the district. The Cambridge limestone is, however, ten or fifteen feet nearer the Coal VI, than in most sections."

§ 30. The intervals in this section, as given by Orton in the Geology of Ohio, Vol. III., page 926, are measured, as is customary in that vicinity, from Coal VI; but to facilitate comparison with that given on page 4 of the present essay, we have reckoned them from the place of the Ferriferous limestone, ten feet below the base of Coal V. The summit of the hill at the mouth of Meeker's Run, is 207 feet above the railroad, and includes, according to Andrews, about twenty-seven feet of strata above the Cambridge limestone. The limestones and iron-ores of the section will be noticed in their proper places.

*Section of Coal-Measures on Meeker's Run in York.*

| Feet. | |
|---|---|
| 218 | Cambridge limestone. |
| 153 | Iron Point ore; 25 inches, overlaid by about 50 feet of heavy sand-rock, with red shales above. |
| 135 | COAL VII; 4 feet, with sandstone, followed by shales, above. |
| 126 | Buchtel ore; 15 inches, with shales above. |
| 113 | Shawnee limestone, 18 inches, followed by 12 inches of ore, and shales above. |
| 97 | COAL VI*b*; 12 inches, with sandstone above. |
| 91 | Norris limestone, 12 inches, overlaid by 6 inches of ore, with shales above. |
| 76 | COAL VI*a*; 3 feet, with sandstone above. |
| 48 | COAL VI; 6 feet 11 inches, with shale roof and sandstone above. |
| 39 | Snow Fork ore; 8 inches, with shales above. |
| 10 | COAL V; 2 feet, with sandstone above. |
| 0 | Place of Ferriferous limestone, with white fire-clay beneath the overlying coal. |

§ 31. We note in this section, besides the absence of the Ferriferous limestone and its associated iron ore, that of the small coal seam VII*a*. With these exceptions, Orton observes with regard to this section: "It answers without change for all the leading elements of the scale throughout the western part of York township and the eastern part of Starr, and through Brown and Madison townships or, in other words, to the line of the Marietta and Cincinnati Railroad. It is repeated with almost identical measurements in Rich Hollow Hill, three miles north-east of Zaleski [section 30 of Madison township], where the westernmost exposure of the Cambridge limestone in that vicinity is found." (Geological Survey of Ohio, vol. III., pp. 926–928.)

§ 32. We may now proceed to give some details with regard to the distribution and relations of these upper coals in the Hocking Valley field. Beginning at the north-west, we find, according to Andrews, in section 2 of Monday Creek township, above the Great Vein, there reduced to a thickness

of four feet, two unopened coal-beds, separated from the last, and from each other by intervals of twenty-five and twenty-seven feet respectively. Near Shawnee, above the Great Vein, here measuring not less than eleven feet, there are, according to Read, two similar seams, the upper of which attains in parts a thickness of four feet, and yields a good coking coal.

§ 33. In various places in Salt Lick, Ward, and York, there is found, as Andrews has shown, a seam of coal from eighteen to thirty feet above the Great Vein, generally separated from it by yellow-weathering shales. Thus, according to this observer, we find in the north-east corner of Ward, on Snow Fork, a seam of three feet of coal twenty-five feet above the top of the Great Vein, followed, after twenty-seven feet, by about two feet of limestone, with some iron ore, while at sixty feet above the same horizon, is a second seam of coal, measuring 4′ 3″, and a third seam of 3′ 6″, thirty feet higher, or about 100 feet above the bottom of the Great Vein. Lower down the valley of Snow Fork, however, in section 4 of Ward, the first of these is apparently absent, but a seam of four feet of coal is found forty-eight feet above the Great Vein, while the outcrop of another is seen forty-five feet higher. These three seams of coal above No. VI would correspond to those designated VI*a*, VI*b*, and VII, shown in the Meeker's Run section a little farther south.

§ 34. The strata from above the Cambridge limestone to a point below the Great Vein are well exposed in a hill-side on what is known as the Cawthorn land, in section 7 of Ward, the property of the Hocking Iron Co., where the levels of the various outcrops have lately been taken with care under the direction of Mr. J. Cummings, the manager of the company. The results, showing elevation in feet, but rejecting fractions, and omitting the ore-beds, are given below, side by side with those for the corresponding strata in the Meeker's Run section, to facilitate comparison with which

the position of the Great Vein is placed at the same elevation above the zero-point, though this interval has not been measured in the Cawthorn section. See in this connection the general section on page 4.

*Sections in Ward and York Compared.*

| | Cawthorn. | Meeker's Run. |
|---|---|---|
| Cambridge limestone, | 284 | 218 |
| Coal VII*a*, | 189 | wanting |
| Coal VII, | 150 | 135 |
| Shawnee limestone, | 110 | 113 |
| Coal VI*b*, | wanting. | 97 |
| Norris limestone, | wanting. | 91 |
| Coal VI*a*, | 77 | 76 |
| Coal VI, | 48 | 48 |
| Ferriferous limestone, | 0 | 0 |

In the earlier reports on this region, and indeed until recently, it was supposed that there existed but a single seam of coal between VI and VII, which was designated by myself and by others VI*a*, and assigned a place, as we have seen, from fifty to sixty feet above Coal VI. Since, however, another seam has been recognized in many parts of the field between these two, it must take the name of VI*a*, while that next above it (the former VI*a*) becomes VI*b* in the notation here adopted from Prof. Orton's report on this region for 1878.

§ 35. A comparison of the above two sections shows us: first, the apparent absence from the Cawthorn section of the seam of Coal VI*b*, which, though only one foot thick in the Meeker's Run section, attains in many places four feet or more; second, the variable thickness of the Coal VII, which, while measuring four feet in the section last named, is only one foot in thickness on the Cawthorn land, where it is separated by two feet of black shale from a strong and massive overlying sand-rock, twenty feet or more in thickness; third, the variation in the interval between the coals

VI and VII,—from 87 feet in Meeker's Run to 102 feet in the Cawthorn section. To this corresponds a like difference in the elevation of the Cambridge limestone, the distance between which and Coal VII is however unchanged, being in the two sections respectively eighty-three and eighty-four feet. We also note the absence from the Meeker's Run section of the Coal VII*a*, which on the Cawthorn land is about a foot in thickness, and 140 feet above the Great Vein, and which in parts of the field becomes an important seam.

§ 36. From these sections it is apparent that there are found in parts of the Hocking Valley field not less than four seams of coal between the Great Vein and the Cambridge limestone, or within a distance of less than 150 feet from the floor of Coal VI. Their close proximity has rendered the study of these difficult, from the possibility of confounding them one with another, and even with the Great Vein itself. To add to this difficulty these coals are all very variable in thickness, and one or more often becomes reduced to a thin layer, or is entirely wanting in the series. On the other hand, each of these occasionally assumes a thickness of four feet or more, and becomes a valuable coal-seam over considerable areas. Many of these points are illustrated by the two sections above given, and others will be made evident in the farther description of the coal-field.

§ 37. Passing from these localities, in section 7 of Ward and section 16 of York, to the north-east corner of York, we find numerous outcrops both of the Great Vein and of the higher seams, the elevations of all of which have been carefully determined by Mr. W. H. Jennings, chief engineer of the C. & H. V. R. R., to whom I am indebted for the levels. Near the western border of section 6 of York, on the south side of Snow Fork, two coal-seams have lately been opened by Mr. Buchtel, above one another, in the same hill-side; the lower of these being the Great Vein with a thickness of nine feet, 125 feet above Lake Erie; and the other, six feet in

thickness, 205 feet above the same level, making an interval from the base of one to the base of the other of eighty feet. The outcrop of an intermediate seam, the level of which has not been determined, is here observed. About half a mile to the northward, in the N. W. corner of the same section of York, there are several outcrops of coal-seams the levels of which have been measured, from which it appears that the interval between Coal VI and the upper seam is, as before, about eighty feet, while an intermediate one occurs about fifty above the former. Again, from observations at several points within a mile and a half to the south-west of the Buchtel openings, it appears that the interval between the Great Vein and the upper seam varies from ninety to eighty feet, and perhaps less. At one point in this direction a limestone band is seen about twenty-five feet below the upper coal, while within a short distance to the north-east, and nearly in the line of strike from the Buchtel openings, are two outcrops of limestone at elevations of 187 and 183 feet, or about twenty feet below the upper coal. These outcrops of a coal-seam from eighty to ninety feet above the Great Vein, and of a limestone from twenty to twenty-five feet lower, correspond closely to Coal VII and to the Shawnee limestone, while the intermediate seam occupies the place of Coal VI*b* in the Meeker's Run section.

§ 38. About a mile south-east of the Buchtel openings, in Happy Hollow, which is in the N. E. quarter of section 5 of York, are two coal-openings, on the banks of a small creek, within a few hundred feet of each other, which are 163 and 165 feet, giving a mean of 164 feet elevation above Lake Erie. The coal here mined for shipment and for coking, with a thickness of from four to five feet, has above it, at 233 feet, another coal-seam of three feet, regarded as Coal VII*a*, and at 275 feet the Cambridge limestone. The interval between the last two is here forty-two feet, and in the Cawthorn section is forty-five feet. That between the same limestone and

Coal VI*b* in the Meeker's Run section, is 121 feet, while the coal mined in Happy Hollow lies 111 feet below the Cambridge limestone. We have, however, already seen, that in the last named section the interval between this limestone and Coal VI is less than usual in other parts of the field (§ 29). Coal VII*a*, which is not recognized in the Meeker's Run section, is found in the Sunday Creek valley, and in the Cawthorn section, at an interval above Coal VII varying from thirty to forty feet, while it lies sixty-nine feet above the coking coal mined in Happy Hollow.

§ 39. If now we endeavor to fix the elevation of the Great Vein at this locality, we find from a comparison of the levels of several outcrops of it within a mile or two, some of them nearly in the line of strike, that as a consequence of slight irregularities, due to local undulations, it may vary between 101 and 110 feet, giving thus for the interval between Coal VI and the seam mined at Happy Hollow from sixty-three to fifty-four feet. That deduced by Mr. Jennings from outcrops of the two coals, about a mile to the southward in section 4 of York, is fifty-five feet. These considerations confirm Orton's view, that the seam in question is really VI*b*, or the so-called Norris coal. It may here be mentioned that outcrops both in sections 5 and 6, show the presence of another seam intermediate between the last and the Great Vein, from which it is separated by an interval of from twenty to thirty feet, and which is apparently the Coal VI*a*. We have thus in sections 5 and 6 of York, within about 150 feet from the base of coal, all of the seams of coal found in the Meeker's Run section, with the addition of VII*a*.

§ 40. Passing now to the western part of York, we find in fraction 18, which is south of section 35, the Coal VI*b*, according to Andrews, with a thickness of only nine inches, while a mile and a half further to the south-west it appears with a thickness of four feet. In fraction 11 of York, on the land of Dr. Elder, two seams of coal are seen, the lower of which,

here mined for local use, and four feet in thickness, is a coking coal having a yellowish limestone a few feet above it. The upper seam, after an interval estimated at about forty feet, is also a coking coal from three to four feet thick, which is overlaid by a strong, massive sandstone forming a conspicuous feature in the hills, and often twenty feet or more in thickness in this part of the coal-field.

§ 41. About a mile to the north-west of this locality the lower seam is also mined, with a thickness of four feet, and here, I am told by Dr. Elder, the Great Vein was found, in sinking a well, with a thickness of six feet, forty feet from the surface, and at an estimated interval of fifty feet from the lower seam. It will be remembered that Coal VI is also exposed with a thickness of six and a half feet a little farther southward in the valley of Spring Run, in section 32 of York. The two seams above it just noticed are apparently Coals VI*b* and VII.

§ 41A. Passing thence down the east branch of Raccoon Creek, towards Carbondale, we observe numerous outcrops of these two seams, the higher overlaid by the heavy sand-rock; while the lower, generally not far above the water-level, is opened in several places with a thickness of four feet and upwards; a Ferruginous limestone, with a marked ore-stratum a little above it, being seen at many points between the two coals. A little farther east, towards the head-waters of Floodwood Creek, I found two openings of what was regarded as the lower coal, VI*b*, measuring respectively 3′ 11″ and′ 4 6″.

§ 42. At Carbondale, in section 36 of Waterloo, where the lower of these seams is extensively mined, it has a thickness of four feet, which in the levels to the eastward is said to augment to five feet. Above this is found an upper seam, overlaid by heavy sand-rock, and between the two a limestone with an ore-stratum overlying it, as already described. The upper seam is said to be opened near by with a thickness of

three feet, and to be a fat coking coal. We have already cited the opinion of Read (§ 19), that Coal VI, which is seen in the north-west corner of section 36, passes about fifty feet below the seam mined at Carbondale, and I was informed in 1873, that borings then lately made at Carbondale had shown the Great Vein, with a thickness of six feet, at the same interval of fifty feet below, a thin intermediate seam of coal being met with.

§ 43. Farther southward, in the western part of Waterloo, at Mineral City, and at King's Switch, both stations on the M. & C. R. R., a seam of coal between two and three feet in thickness is mined for shipment. The coal of these two localities is, by Andrews and by Orton, in their later reports, supposed to be the same as the Carbondale. An earlier report and section by Andrews, however, makes the Mineral City coal to be a seam some twenty-five or thirty feet above that mined at Carbondale, and farther inquiry seems necessary to determine which of these two views is correct.

A seam of coal referred by Orton to the same horizon as that of Mineral City and King's Switch, is opened on fraction 6 of Brown, near Hope Furnace, with a thickness of three and a half feet. About thirty feet below this is another seam of a foot, and it is reported that a boring of forty feet at this place reached the Great Vein.

§ 44. Mention has already been made (§ 13) of the shaft on the land of Mr. H. Heasley in fraction 25 of Brown, near Hope Station on the M. & C. R. R., where what I regard as Coal VI was found twenty-seven feet below the surface. Above this is found a seam of thirty-three inches, and another higher one of three feet, which is mined. These are provisionally regarded as representing VI*b* and VII, besides which there is a layer of a few inches of coal, which may correspond to VI*a*, overlying the sandstone which comes above the shaft-coal.

§ 45. Two seams, each from three to four feet, the latter overlaid by heavy sand-rock, are described as occurring in fraction 32 of Brown, where, as already stated, the Great Vein was found in boring for salt at a depth variously stated at from forty to sixty-five feet. Two similar seams were seen in section 23 of Brown, above the Great Vein there exposed, and are believed to be the same with those described by Orton in the adjoining section, 29 of Brown, about forty-five feet apart, and respectively four and five feet in thickness. Two seams, apparently corresponding to these, are seen above the Great Vein in the south-eastern part of Starr, where one, regarded as VI*b*, is now mined, with a thickness of four feet, in section 13.

§ 46. These upper coal-seams in Brown and Starr require to be farther examined, with careful determinations of levels, before their identity can be established. It is uncertain how far Coal VII*a* may be represented in this region beneath the Cambridge limestone, which is found over much of the higher lands in the townships just named. A section by Andrews, a little east of Carbondale, shows a third and unopened coal-seam between forty and fifty feet above what we have regarded as Coal VII, a heavy sandstone intervening. Between one and two miles farther east, in section 24 of Waterloo, I found a little above the sandstone, there conspicuously seen, two outcrops of a seam of coal, in one place mined for local use, with a thickness of about two feet; while below the sandstone, here twenty feet or more in thickness, appeared the Coal VII, which was traced thence eastward to Hamley's Run. The seam lying above the sandstone was regarded as VII*a*, and is probably the same with that found farther to the south-east, on the line of the M. & C. R. R., where it is mined, at the Steiger bank, three miles west of Athens.

The farther consideration of the upper coals in the south-eastern part of the field, will be given in connection with the

Sunday Creek valley, to the description of which we shall now proceed, beginning with its upper or northern portion.

§ 46. In the upper part of the Sunday Creek valley the coal VI*b* is generally known as the Norris seam, being identified with that mined at the Norris bank near Millertown, in section 21, not far from the centre of Monroe, where it measures 5′ 6″, including two thin shale partings and 10″ of cannel coal at the base. It is here said to be forty-five feet above the Great Vein. Near Buckingham, on the land of Benjamin Saunders, in section 19 of Monroe, it is reduced to 2′ 6″ in thickness, and is said to be forty-seven feet above the Great Vein, here visible. In another exposure near the last, the Coal VI*b* measures 2′, and where seen by me in section 31 of Monroe, is 2′ 6″, while in section 9, at the Sands bank, where it is mined for local use, it has a thickness of 4′ 2″, without a parting, and with a heavy shale roof. It is here fifty feet above the Great Vein. At Ferrara, in section 22, it is but a few inches in thickness, and at one place in the neighborhood is represented by a shaly layer with but a single inch of coal.

§ 47. To the north of Monroe, at Moxahala, according to Read, where the Great Vein is reduced to four feet, the Coal VI*b* is found fifty-two feet above its base; but the average interval in this vicinity is said to be about forty-nine feet. This upper coal at Moxahala measures 4′ 2″, and has a two-inch shale parting just above the middle of the seam. It is seen again in section 4 of Pleasant township, and also at Oakfield, in section 29, where it has been mined for some years; while to the north-west, near New Lexington, it is altogether wanting, its place being filled by sandstone.

The coal of this seam may, according to Andrews, be traced in most of the hills throughout the northern part of Sunday Creek valley, "but sometimes fails altogether." In the language of Orton, this coal "is capricious in its development," and, although seldom entirely absent, it

changes "from five feet to as many inches with rapid alternations." This Norris seam, VI*b*, appears, wherever mined, to be, unlike the Great Vein, a coking coal.

§ 48. Above the Norris coal, in the upper Sunday Creek valley, at an interval varying, according to Read, from twenty-five to forty feet, there is found another seam of coal, which reaches a maximum thickness of between four and five feet, and is locally known as the Four-foot or the Stallsmith coal. It is mined on the land of Benjamin Saunders, in section 19 of Monroe, where it is said to show 4′ in a single bench, besides 8″ additional above a thin pyritous layer. At the Stallsmith bank, in section 30, where I lately saw it, this seam yields 4′ of fat coking coal, and is immediately overlaid by a stratum of iron ore, a lower seam, also of coking coal, 2′ 6″ thick, and apparently VI*b*, being visible in a valley near by. Passing down Indian Run, in section 32 of Monroe, this upper coal is over 5′ thick, and is separated by an estimated distance of thirty feet from the Norris coal, here 4′ in thickness. This uppermost coal is apparently, like the two beds below it, irregular in its thickness, and resembles them in being a coking coal.

§ 49. To the west of Monroe, in the vicinity of Shawnee, there are, as already pointed out (§ 32), two coal-seams, the upper one of which is opened near Shawnee in section 21, and shows three and a half feet of coal. The elevation of these above Coal VI is not known, though they are conjectured to be VI*b* and VII. A little to the south-east, on the lands of the Straitsville Cannel Company (sections 14 and 23 of Salt Lick), a shaft disclosed Coal VII with a thickness of four feet ten inches, at ninety-two feet above the base of Coal VI; while forty-four feet higher, or 136 feet above VI, is another seam of six inches of coal, regarded as VII*a*. This locality will be farther noticed in speaking of the iron-ores of the region.

Above this there are, in places, according to Read, "two or three thin seams of coal, but at no point observed are they of economic value, except at the village of Bristol, west of Moxahala, where the hills rise about 250 feet above the Great Vein. There, near the top, a coal is mined which is locally 4′ 6″ thick. It is a soft, melting, bituminous coal of very fine quality. Mr. Nichols's section makes this coal 230 feet above the Great Vein."

§ 50. In the townships of Trimble and Dover, which are included in the lower Sunday Creek valley, we find, so far as known, no seam of coal above the Great Vein until we reach what is there called the Bayley's Run coal, from the fact that it has long been mined on the stream of that name in Dover. It is throughout this lower valley a very persistent seam, with a thickness of from four to five feet, being seldom less than four, and it has a thin parting about one-third from the top. It is, says Andrews, "a seam of wide range, and may be found almost everywhere where the hills are high enough to contain it, though it sometimes fails." It is a cementing or coking coal of excellent quality.

§ 51. From the record given by Andrews of the Chappalear well, sunk on the town-site of Ewing, in section 7, in the south-east part of Trimble, it appears that between the Bayley's Run coal, here 4′ 8″ thick, and Coal VI, which measured 8′ 4″, there intervene 87′ 10″ of strata, mostly shales, with two included beds of limestone, but no intermediate coal-seams. The interval from the bottom of VI to that of the Bayley's Run coal is thus ninety-five feet.

§ 52. Again, in fraction 36, which is near the centre of Trimble, is a trial-shaft known as the Blonden well, also cited by Andrews, which I have lately visited, and have obtained from Mr. J. W. Jones, who superintended the sinking of it, and is familiar with the region, a confirmation of the data given by Andrews, with additional details. In the shaft, which was four by six feet, the Bayley's Run coal was

reached at twenty-one feet from the surface, and measured 4′ 8″. It was succeeded, in descending, by seventeen feet of shale, and three feet of iron ore, including a little shale. Below this were thirty-eight feet of light-colored and four feet of dark shale, the latter immediately overlying the Great Vein or Coal VI, here 12′ 2″ thick; while twenty feet below the base of the latter there was found Coal V, with a thickness of 2′. The interval from the base of VI to that of the Bayley's Run coal was thus seventy-nine feet, instead of ninety-five feet, as in the previous case, and here again, I am assured that no intervening seam of coal was found.

§ 53. According to a note furnished me, however, there was found in shafting for coal at the mouth of Hamley's Run, near Salina, in south-west Dover, a thin seam forty-five feet above the Great Vein, and a similar thin seam is said to have been met with in the shaft through which this coal is mined at Chauncey.

The register of the boring of one of the salt-wells at Salina, which are carried to a depth of 600 feet, gives the Great Vein, here six feet thick and ninety-eight feet from the surface, as the first coal met with. It was underlaid, at a depth of thirty-three feet, by a seam of coal having a thickness of two feet, probably Coal V. The record makes no mention of any lower coal-seam. The Bayley's Run coal is here just at the surface, and on the north-east side of the Hocking River, near by, is mined for local use, with a thickness of four feet and upwards. Previous to sinking for the Great Vein, this upper coal was used for the manufacture of salt at Chauncey.

§ 54. The absence of any considerable seam between the Great Vein and the Bayley's Run coal is recognized by all those who are familiar with the geology of the lower Sunday Creek valley. The Rev. J. P. Weethee, to whose studies Prof. Andrews declares himself much indebted, and who furnished for volume I. of the Geological Survey of Ohio

(pp.268–271) many details of the region, there says: "The next seam above the Great Vein crops out everywhere along the lower Sunday Creek valley, and is regular in position and uniform in thickness. At the mouth of the Creek [in southern Dover] it is five feet above low water, and at the north-east corner of section 12 of Trimble [near the line of Monroe] it is four and a half feet above low water. It is worked at five points in Dover and eleven in Trimble, to the west of Sunday Creek, . . . and supplies coal for the whole of the lower Sunday Creek valley. It appears along all the western tributaries, and can be advantageously mined through the whole western half of the district under discussion"; that is to say, the parts of Trimble and Dover lying west of Sunday Creek.

§ 55. From the report above quoted we copy the following measurements of the Bayley's Run coal in the townships just named. The thickness indicated includes in most cases a shale parting of about two inches.

*Bayley's Run Coal.*

| | | | | |
|---|---|---|---|---|
| Mouth of Sunday Creek, | Section | 20, | Dover, | 4′ 6″ |
| Weethee's Bank, . . | " | 12, | Dover, | 4′ 7″ |
| Bayley's Run, . . | Fraction | 34, | Dover, | 4′ 6″ |
| Southerton's Bank, . | Section | 34, | Dover, | 4′ 2″ |
| Mount Auburn, . . | " | 18, | Dover, | 4′ 2″ |
| James Rutter's Bank, . | " | 10, | Dover, | 4′ 8″ |
| Greene's Run, . . | " | 19, | Trimble, | 4′ 8″ |
| Johnson's Bank, . . | Fraction | 18, | Trimble, | 4′ 9″ |
| Allen's Bank, . . . | " | 2, | Trimble, | 4′ 8″ |
| Newton's Bank, . . | Section | 5, | Trimble, | 4′ 6″ |
| H. Edwards's Bank, . | " | 24, | Trimble, | 5′ 3″ |
| Rich. Stover's Bank, . | " | 23, | Trimble, | 4′ 6″ |
| Newton's Bank, . . | " | 11, | Trimble, | 4′ 3″ |
| Blonden Well, . . | Fraction | 36, | Trimble, | 4′ 9″ |
| Chappalear Bank, . . | Section | 7, | Trimble, | 4′ 8″ |

§ 56. The Bayley's Run coal is, by Orton and by Andrews, regarded as Coal VII, and the intervals observed of seventy-nine and ninety-five feet between it and the Great Vein, correspond nearly with those already given (§ 34) in eastern Ward and York, on the opposite side of the high ridge which separates Sunday Creek valley from that of Snow Fork and Monday Creek. Over this it is not possible to trace the coal, but it may be followed across the lower levels of southern Dover, through the adjacent parts of Waterloo and York into Ward.

§ 57. The Bayley's Run coal is seen in the south-west corner of section 31 of Dover, with a thickness of 4′ in the valley of Hamley's Run, and farther to the south-west, in section 12 of Waterloo, where there are several openings in this coal-seam on the land of Mr. Young, in one case a drift of 100 yards. The coal is here 4′ thick. A boring in this section to a depth of sixty-four feet reached the Great Vein with a thickness of 7′, no coal-seam occurring in the interval. The base of the upper coal was here estimated at fifteen feet above the top of the boring, which would give a distance of eighty-six feet from the base of one to the base of the other. This upper seam is also said to be opened on section 18 of Waterloo. It was observed again in the north-west corner of section 6, where the seam, with a thickness of between three and four feet, and overlaid with a foot of shale, is opened beneath a mass of heavy sandstone; a limestone being seen between twenty and thirty feet below. This coal appears to be the same with that we have described in various parts of York as Coal VII, to which we therefore, with Orton and Andrews, refer the Bayley's Run seam.

§ 58. Prof. Read, however, supposes that the Bayley's Run is identical with the Norris coal of the upper Sunday Creek valley, and regards the Stallsmith seam, which there overlies the latter, as corresponding to what we have called Coal VII*a*. This lies in the Cawthorn section thirty-nine

feet above Coal VII, and in the lower Sunday Creek valley is found, according to various observers, from thirty-five to forty-five and even fifty feet above the Bayley's Run seam, where it is sometimes known as the Splint coal, and though generally thin, occasionally attains a thickness of four feet, and is closely associated with iron ores. Commenting on the view of Prof. Read, Andrews remarks: "I see no reason for changing my original opinion that the Bayley's Run and the Stallsmith seams are the same;" and he adds that traces of this Splint coal are found in the upper Sunday Creek valley, at the usual interval above the Stallsmith coal. (Geol. Survey of Ohio, vol. III., page 857.)

§ 59. The interval between Coals VI and VII*a* in the lower Sunday Creek valley, is not far from 140 feet (135 ft. according to a section by Weethee in Trimble), and the seam VII*a* may perhaps correspond to that mined at the Steiger bank already mentioned as opened on the M. & C. R. R., three miles west of Athens; where it has long been mined for domestic purposes, and for the manufacture of salt, and has a thickness of four feet ten inches, including a shale parting of two inches. The salt-well here bored is reported to have disclosed the Great Vein, with its usual thickness, at a depth of 140 feet below the Steiger coal.

§ 60. Still another and higher coal-seam occurs within the limits of the Hocking Valley coal-field, which, although not of economic value, is of some importance in fixing the horizon of the iron-ores in the region. It is a thin seam, so far as known, not more than one or two feet in thickness, which lies sixty or seventy feet above the Cambridge limestone, or about half-way between this and the Ames limestone, and may be conveniently designated as VII*c;* inasmuch as Orton has called VII*b* a coal-seam, which, though not yet met with in the Hocking Valley field, is found in the more southern counties of Ohio, closely associated with the Cambridge limestone, and is there mined for local

use. The general section given by Orton makes no mention of any coal-seam between the two limestones just named; but besides VIIc, there are said to be traces of another thin seam nearer the Ames limestone.

§ 61. In explanation of the varying intervals between coal-seams so often recorded, it should be said that the shifting currents which laid down the sediments covering a coal-bed, often deposited in some places a larger amount of sand and gravel, and near by at the same time greater quantities of clay and fine mud, until the level of the next coal-seam was reached. In the subsequent consolidation of these materials into rock, the shrinking of the clays under pressure would be more considerable than that of the sands, from which it results, as well remarked by Andrews, that the interval between two contiguous coal-seams is greater in the areas when there is a large amount of sandstone, and less where the shales predominate.

§ 62. Some degree of uncertainty often attaches to observations of levels in a hilly country of horizontal or nearly horizontal strata like the present, for a reason well set forth by Prof. Read, who remarks: "Massive slips upon the slopes of hills are throughout this whole region so numerous that there is great difficulty in securing accurate measurements of the intervals between the ore and coal-beds, and measurements reported can be verified only after the regular opening of the mineral deposits."

§ 63. It has already been stated that the inclination of the strata in this coal-field is very slight, varying from fifteen to thirty feet to the mile in a south-eastward direction. A detailed discussion of numerous determinations of levels of the Great Vein of coal will be found as a supplement to this report, from which it will appear that the inclination of this seam is from fifteen to twenty feet to the mile along the north-western border of the field, and augments to thirty feet as we pass south-eastward.

*Limestones of the Coal-field.*

§ 64. By a reference to the general section on page 4, it will be seen that there are four main limestone deposits indicated in the coal-measures of the Hocking Valley, beginning with the Gray or Ferriferous limestone, which we have regarded as the base of the series for this coal-field. There are, however, two lower ones which may here be mentioned: the first known as the Blue or Zoar limestone, which, beyond the western border of the field, lies about 100 feet below the Gray limestone; and the second from 100 to 135 feet below the Blue, called the White or Maxville limestone; the three colors named being in a general way characteristic of the three limestones. Inasmuch, however, as the White and Blue limestones nowhere appear within the limits which we have assigned to the Hocking Valley coal-field, details respecting them are here unnecessary.

§ 65. The Gray limestone, the first and lowest mentioned in our section, is often called the Ferriferous limestone, since, notwithstanding most of the other limestones to be described are more or less ferriferous or iron-bearing, this one is, throughout what is called the Hanging-Rock iron-region, south of the Hocking-Valley coal-field, accompanied by the iron-ore which chiefly supplies its furnaces. Hence it is called the Hanging-Rock limestone. The Putnam-Hill limestone, which is found farther north and east, beyond our limits, is by some regarded as its stratigraphical equivalent; but the connection of this with the Gray limestone of the Hanging-Rock region is not clear, and in the opinion of Orton its place is about twenty feet lower in the series. The Gray limestone with which we have here to do, is traced from Bristol, in Perry County, along the north-west border of the field, though thinner and less regular than farther south towards the Ohio. Its position is from forty to fifty feet below Coal VI, and its thickness varies from two or three to seven feet and more. It is generally light gray in color,

somewhat crystalline in texture, and abounds in fossils, in large part crinoids. When burned, it yields a nearly pure lime, and it furnishes a flux for numerous iron-furnaces along its outcrop. In some parts of its distribution, however, it assumes a darker color, and it is frequently associated with flint or chert, which sometimes wholly takes the place of the limestone, giving rise to beds of flint, which, resisting decay, take the form of ridges. From this material, in the earlier times of settlement, mill-stones were wrought. Resting upon this limestone is found the famous Hanging-Rock ore or Baird ore, to be noticed farther.

§ 66. The second formation noticed is that of the Buff limestone, called also the Shawnee limestone, from the fact that it is largely used as flux in the blast-furnaces around Shawnee. Its thickness varies from one to three feet, and is generally not over two; it sometimes forms nodular masses. It holds but few fossils, and is not, so far as known, accompanied by flint. Much of this limestone is nearly pure, but it often contains a portion of carbonate of iron, which causes it to take a yellowish or buff color on its weathered surfaces. This limestone is accompanied by an iron-ore known as the Straitsville ore.

§ 67. Between the Shawnee limestone and the Gray limestone below, there are found in parts of the field two other horizons of buff-weathering limestone, which are, however, local. One of these, from twenty to thirty feet below the Shawnee limestone, and consequently just below the Coal VI*b*, or Norris coal, is seen in the Meeker's Run section in York (page 19). Like the Buff limestone above, it is associated with an iron-ore, and the two have been called the Norris limestone and the Norris ore. This limestone is irregular in its distribution, and seldom exceeds two feet in thickness. Another buff-weathering limestone, lying from twenty to thirty feet above Coal VI, is seen in several parts of the valley of Snow Fork, and has been called the Snow-Fork limestone.

§ 68. Between the Shawnee limestone and Coal VII, in the section just referred to, is placed the Buchtel ore. This is generally accompanied by nodular masses of an impure ferruginous limestone, and in the lower Sunday Creek valley by a limestone formation several feet in thickness, underlying the ore. A limestone at this horizon is also well marked, according to Orton, in the more southern parts of Ohio. This subordinate formation, which may be called the Buchtel limestone, will be farther noticed in speaking of the iron-ores of the region.

§ 69. We come next to the Cambridge limestone, which takes its name from Cambridge in Guernsey Co., where it is well developed. Its color is generally grayish or brownish, but it is sometimes dark-bluish or black, and hence it is locally called the Black limestone. Its position is from 110 to 120 feet above the Shawnee limestone in the Hocking Valley. It is somewhat fossiliferous, and in parts of its distribution is replaced by flint. The thickness of the Cambridge limestone varies from two to eight or ten feet. In some parts of the field two limestones are found at this horizon, which, as the interval between them varies from a single foot to twenty feet, are regarded by Orton as belonging to one formation, and designated by him as the Upper and Lower Cambridge. These are seen divided by ten or twelve feet of shales in parts of York, and when thus separated by a considerable interval, the upper division appears to be somewhat farther than usual from the Shawnee limestone.

§ 70. The western exposures of the Cambridge limestone are seen in Starr, Brown, and Madison. It is known in the eastern part of Starr, at least as far north as section 5, and thence south-westward to section 18 of Brown, and through that township to section 30 of Madison; underlying doubtless large areas in Brown, in Waterloo, and in southern York. It appears only in the high lands of south-eastern Ward, for it will be remembered the valleys of Snow Fork and Monday

Creek are cut down below Coal VI, and in parts to the level of the Gray limestone. In the hills of western Trimble and Dover, however, the Cambridge limestone again appears, and underlies the high lands eastward, nearly to the valley of lower Sunday Creek, which, as we have seen, flows not far from the level of Coal VII, or about eighty feet below the horizon of the Cambridge limestone.

§ 71. At an elevation of about 120 feet above the Cambridge is found the Ames limestone, so called from the township of that name in Athens Co. It is light gray, sometimes slightly reddish, more crystalline than those previously noticed, and abounds in organic remains, often of crinoids, from which it is sometimes designated by the Ohio geologists as the Crinoidal limestone. Its thickness is generally from two to three feet, but it rises to five, and in parts of Trimble to fifteen feet. It yields a pure lime, and will be valuable as a flux for blast-furnaces.

From its elevation in the series this limestone is found over but a small part of the Hocking-Valley field. It appears on the east side of the Snow Fork valley, in section 33 of Trimble, and is also known in sections 36, 29, and 33 of Dover, doubtless underlying all the higher lands in the hills eastward towards the lower Sunday Creek valley. To the westward I have found it in section 13 of York, and it is reported in south-eastern Brown. It is probably present at many points in the higher lands of Brown and Waterloo, judging from the wide distribution of a horizon of red hematite ore, which lies a little below the Ames limestone and is seen in south-eastern Starr, in sections 13 and 19 of Brown, and in northern Waterloo.

§ 72. In the interval between the Cambridge and Ames limestones and, according to Orton, about eighty feet above the former, is a subordinate limestone, said to be highly charged with iron, and to be generally found in the form of nodules in a layer of red earth, being very often concealed

by the results of its own decay. This is called by Orton the Ewing limestone. The Black limestone found near Ewing, in Trimble, which is often ferruginous, belongs, according to Read, near the horizon of Coal VII*a*.

The interval between the Cambridge and Ames limestones in north-western Dover is, according to Jennings, 120 feet. Read, in a general section, makes it 118 feet, while other measurements give 100 feet, or even less. These discrepancies perhaps arise from the separation of the Cambridge into two parts, as already described.

### *Iron-Ores of the Coal-Field.*

§ 73. The iron-ores of the coal-measures of the Hocking Valley are, like the limestones with which they are often closely associated, interstratified at various horizons in the series, and like these, some of them are persistent over wide areas, while others are more local and limited in their extent. They are, with some exceptions, either carbonate of iron or the limonite resulting from its alteration, the exceptions being the red hematite to be mentioned farther on. These carbonates of iron, generally known as gray or blue ores, vary widely in their texture, their mode of occurrence, and their associations. Thus, they may be either compact, crystalline, or made up of little concretionary grains. They form solid beds, either with or without lamination, or appear as rounded masses, often a foot or more in diameter, lying side by side, as in a pavement; or else scattered through soft shaly rocks, forming what is called kidney ore. Sometimes the bedded carbonate of iron is mingled intimately or interlaminated with coaly matter, forming what is called black-band ore, while at other times it is mixed with a greater or less proportion of clay or sand, or is combined with a portion of carbonate of lime, through which it graduates into an impure ferruginous limestone. It is also, in some cases, combined with variable portions of carbonate of

magnesia and carbonate of manganese; besides which, small quantities of sulphur-compounds and of phosphates are generally if not always present.

§ 74. The characters above noted are not always persistent. The same deposit of ore may appear as bedded and laminated, or in rounded blocks and kidneys, in different parts of its extension; while a bed of black-band may, by the disappearance of its coaly matter, lose its distinctive marks, or by the absence of the iron-carbonate become a seam of coal. In like manner, by the intermixture of carbonate of lime a bed of iron-ore may pass, in parts of its distribution, into a limestone. Masses of this kind, which are sometimes mistaken for iron-ore, are found, on analysis, to consist in great part of carbonate of lime with a little iron, sometimes with a large admixture of clay.

§ 75. By exposure to the action of air and water these carbonate ores soon undergo a chemical change, which consists in the loss of carbonic acid and the absorption of water and oxygen. The resulting compound, a hydrated peroxyd of iron, is what is called brown hematite ore, which is limonite, or more rarely some related mineralogical species containing a less amount of water. At the same time, if the conditions are favorable, any carbonate of lime present is removed by solution, leaving behind only the hydrated peroxyd of iron, together with any clay or sand which may have been present in the original ore. The carbonates of iron are generally changed into a reddish-brown limonite near the outcrop of the beds, or wherever these lie beneath a thin layer of rock; but by drifting or sinking a little distance from the surface they will be found to retain the characters of the blue or gray ore; which however becomes brown from superficial change, after a few months' exposure to the weather. The change goes on from the surface, so that the outside of a block or kidney is often limonite, while the interior portion is still an unaltered grayish or bluish carbonate ore.

§ 76. Pure carbonate of iron contains, in round numbers, 48·0 per cent. of metallic iron, but when thoroughly roasted or calcined loses 31·0 per cent. of its weight, there being left 69·0 per cent. of peroxyd of iron. By its conversion into limonite it loses 20.0 per cent. of its weight, and this limonite, if calcined, leaves peroxyd of iron as before; the pure limonite consisting, for 100 parts, of about eighty-five parts of peroxyd of iron and fifteen of water. The peroxyd itself contains 70·0 per cent. of metallic iron. The above calculations apply to pure ores, which are free from lime, clay, sand or coaly matter.

§ 77. The specific gravity of pure carbonate of iron may be taken at 3·6 (water being 1·0), while that of the limonite formed from it is from 3·6 to 4·0. Taking the less number, which is also the specific gravity of the carbonate, it follows that 100 parts of the latter in their conversion to eighty parts of limonite will suffer a contraction of 20·0 per cent., or one-fifth of their volume. As a result of this the limonite is often a porous or spongy mass. In the case, however, of kidneys or blocks of very compact ore, the conversion beginning at the outside of the mass, an external layer of compact limonite is formed, and then another within this, and still another, till the change is complete. The void space resulting from the contraction is then found between the layers, which are arranged like the coats of an onion, or sometimes wholly at the centre, where a cavity will be formed, holding in many cases, more or less clay or sand, the impurities of the carbonate, which have been separated in the process of conversion into limonite. In this way are formed the hollow masses sometimes known as bomb-shell ore.

With these explanations we shall proceed to describe the principal ore-horizons in the Hocking Valley coal-field, often noting, in passing, their percentage of iron, but reserving for another place detailed analyses of the more important or better known ores.

§ 78. Beneath the Gray or Ferriferous limestone, which has been taken as the base of our series, are important ore-beds, yielding large quantities of iron-ore. These, though beyond the western limits of the Hocking Valley field, find therein the fuel for their treatment, and thus add much to the value of the region. The ore-deposits found in the interval of 100 feet between the Maxville limestone and the conglomerate below it, which here forms the base of the coal-measures, are scarcely worked, and, so far as known, are of little importance. Immediately above the Maxville limestone, however, is a bed known as the Maxville Block ore, which is mined to some extent in the vicinity of Logan, where it rests upon the limestone and is overlaid by a valuable fire-clay. This ore is irregular in its distribution, and is sometimes found where the limestone is wanting, while at other times the ore itself is thin and worthless, or is absent altogether. Near Logan it is a limonite of good quality, from one to twelve inches in thickness, and yields about forty per cent. of iron.

§ 79. Just below the Zoar or Blue limestone, (which is 130 feet or more higher than the Maxville limestone,) and again at four distinct horizons above it, the whole being included in a range of about 100 feet, are five ore-beds, yielding what are locally known, in ascending order, as Lower and Upper Main Block, Rough Block, Sand Block and Fine Block ores. The Sand Block is accompanied by a local deposit of limestone known as the Gore limestone. These are all mined to a greater or less extent and already furnish important supplies of iron-ore, especially in Vinton County.

§ 80. Another ore-horizon is noticed above these and about fifty feet below the Gray limestone, and is supposed by Orton to take the place occupied farther to the north-eastward by the Putnam-Hill limestone. To this belongs, according to him, a carbonate ore seen at Haydenville, and also the Dunkel ore, which is found over a considerable area

to the north-east of McArthur, from one and a half to two feet in thickness, and is, in the opinion of Orton, second only to the Baird ore in importance, in that vicinity. A few feet higher is still another horizon of excellent ore, found in Vinton Co. about fifteen feet below the Gray limestone. It is also known in Perry and Hocking counties, though scarcely mined. This ore forms a heavy bed about ten feet below the Baird ore at Nelsonville.

§ 81. We come next to consider the ore which in the southern counties of Ohio lies directly upon the Gray or Hanging-Rock limestone, and farther north, in Vinton, Hocking and Perry counties, according to Orton, is represented by the Baird ore, so called because there first made use of by the late Mr. Baird of the Baird furnace in Monday Creek township. Farther southward, however, it is known as the Limestone-ore, from the fact that, unlike most of the ores below it, it is closely associated with a limestone. It appears to be very persistent and very uniform in character throughout the region, and when under cover and unaltered is of a light ashy-gray color, and made up of small grains like the roe of a fish, which have a white clayey coating. This gray ore yields, in the raw state, from thirty to thirty-five per cent. of iron, while the limonite resulting from its change contains forty-five per cent. and upwards. More than sixty furnaces in southern Ohio, chiefly in the Hanging-Rock region as it is called (which includes parts of Scioto, Lawrence, Gallia and Jackson counties), derive their ore-supply from this bed, and the iron made from it is renowned for its excellent qualities. The average thickness of it in the southern counties is said by Orton to be ten inches; but farther northward he estimates it at eight inches, though it is often two or three times that thickness. From less than half an acre, near McArthur, in Vinton Co., 9,000 tons of this ore have been raised, and I have there seen it in a solid bed, measuring two feet and upwards.

§ 82. There are exposed in the vicinity of Old Straitsville, and along the base of the hills in the vicinity of Haydenville, according to Read, three beds of ore below the Baird ore, the precise equivalence of which, in the succession already mentioned, has not yet been determined. The lowest would, however, appear to be at the horizon of the Gore limestone or the Sand Block ore. The next above it is an ore which has been mined by drifting, at Haydenville; while a third deposit, described as a thick bed of blue carbonate, is said to be about fifty feet above the last, and fifteen feet above a thick bed of fire-clay which is mined for the Columbus potteries.

§ 83. As regards the Baird ore to the north of Vinton County, where it has been mined for a considerable extent on the western border of the Hocking Valley field, Prof. Read says: "The Gray [Baird] ore appears to be quite persistent, ranging in thickness generally from one to three feet, sometimes thinning down to a few inches, and in places disappearing altogether. . . . It is largely developed and of excellent quality in the hills about Old and New Straitsville, and in nearly all the hills which reach its proper horizon to the west line of Monday Creek township. Separated in a few places by shale intervening between it and Coal V, its ordinary position is directly beneath the fire-clay of this coal, and it is often associated with a cherty drab limestone. When the ore is well developed it seems to take the place of the coal, the latter appearing only as a faint trace of carbonaceous matter. When drifts have been carried into the hills the ore has been found, on an average, nine feet below the coal, the interval being filled with fire-clay and the ore resting on flint or limestone, and sometimes on sand-rock." (Geological Survey of Ohio, vol. III., p. 654.)

§ 84. Elsewhere Read remarks, with regard to the ores associated with Coal V: "This horizon carries two ores, only one of which I have found largely developed in the same

locality, one directly above and one below the fire-clay; and in all cases where there is a considerable body of ore the coal [No. V] is reduced to a mere carbonaceous shale. The thick bed of fire-clay is a characteristic indication of this horizon. On Mr. Peter Hayden's land, near Haydenville, this ore is from eighteen inches to two feet thick, and of good quality. On the Brooks property, section 19 of Ward [just north of Nelsonville] it is a good gray ore, and its presence is indicated in all the western part of the territory where the horizon of Coal V is above drainage; it ranges from about twenty-five to thirty-five feet below the Great Vein. On Charles Robbins's land, south of Nelsonville [section 23 of York], it is thirty feet below, is two and a half feet thick, and is a rich brown oxyd. On Lost Run [in the N. W. corner of Ward] in the roof of Coal V there is a silicious ore much like the Baird ore, from two to two and a half feet thick, which is also found on Sugar Run. This horizon will evidently furnish a large amount of excellent ore." (Ibid. III., 707.) The Baird ore is also found, according to Read, with a thickness of ten inches, in the vicinity of Moxahala.

§ 85. The shales between Coals V and VI, all along their western outcrop carry ore in many places. From eight to ten feet below the Great Vein, a deposit of ore is seen on Snow Fork, near Bessemer, and has hence been called the Snow-Fork ore. It is often in the form of kidneys, or of rounded blocks or plates in the shales, and is generally a fine-grained and compact carbonate. These are well displayed in the valley of Meeker's Run, in section 16 of York, an average of several blocks from which locality gave me nearly thirty-seven per cent. of iron. Ores of this kind are found in section 19 of Ward, and elsewhere at the same horizon as far northward as Moxahala. Similar ores are found a few feet above Coal VI, in the shales, and it is the opinion of Read that these ores, both above and below the Great Vein, may, in places, be worked to advantage.

§ 86. There are several horizons between Coals VI and VII, where valuable deposits of iron-ore have been met with, generally associated with limestone. Two of these accompany the Norris and Shawnee limestones, while a third, the Buchtel ore, is associated in parts of its distribution with what we have called the Buchtel limestone. (§ 68.) Mention may also be made in this connection, of what, according to Read, would appear to be a fourth ore-deposit, lower than those just mentioned, and said to be seen in section 23 of York, where a nearly solid mass of four feet of nodular ore was opened from fifteen to twenty feet above Coal VI, and just below VI*a*. This would be about the horizon of the local deposit which has been called the Snow-Fork limestone. (§67.)

§ 87. It is noted by Orton that the limestones below the Great Vein of coal are white or blue in color, and more distinct from their accompanying ores than those between Coals VI and VII, which weather to a buff color from an admixture of carbonate of iron, and pass by insensible gradations into calcareous carbonates of iron.

With the Norris limestone, there is found, in some localities, an ore either in nodules or as a layer from fifteen to eighteen inches thick, which has not yet been mined in the region, but is believed by Orton to correspond with the yellow kidney ore of the more southern counties, where, however, the corresponding limestone is wanting.

§ 88. Next above this is the ore already mentioned as associated with the Shawnee limestone, which has recently been mined, to a considerable extent, near Straitsville, and is hence known as the Straitsville ore. It is of good quality, and in places abundant, but is less uniform in its distribution than some of the ores above and below.

To this same horizon is by Prof. Read referred an ore found near Moxahala, in Pleasant township, where large nodules, equivalent to four or five feet of solid ore, are described as distributed through seven feet of shale, the blue calcar-

eous ore yielding twenty-five, and the resulting limonite forty-one per cent. of iron. The same ore is found twelve inches thick in section 10 of Pike, where it is sixty-five feet above Coal VI, according to Read, and has been mined to a large extent by stripping, for smelting at Zanesville. "All the openings here made at the proper horizon, show the ore in sufficient thickness to be profitably mined, and of good quality."

§ 89. The third ore-horizon to be mentioned above the Great Vein of coal, is separated from it by an interval of about eighty feet. This ore was first mined and smelted at the Akron furnace, near the village of Bessemer, in York township, and was hence called the Bessemer ore. This name was, however, misleading, inasmuch as it suggested an ore such as is ordinarily used for the manufacture of Bessemer metal, and has been replaced by that of the Buchtel ore, in compliment to the president of the Akron Iron Company, who first developed and smelted it.

The position of the Buchtel ore on the Cawthorn land, in section 7 of Ward, where it is extensively mined for the Lee furnace, is eighteen feet above the Shawnee limestone, eighty feet above Coal VI, and twenty-two below Coal VII. At the openings of the Buchtel Iron Company, near the eastern limit of section 3 of York, the same ore is found, according to recent levels by Col. Riley, eighteen feet above the Shawnee limestone, from eighty to eighty-five feet above Coal VI, and seventeen feet below Coal VII; while at the workings of the Akron Iron Company, near Bessemer, it is found, as before, eighteen feet above the limestone just named, and eighty-three feet above Coal VI. Elsewhere it is separated by an interval of only seventy-five feet from Coal VI. The diminished distance which we have already found (§ 37) between this coal and what we have regarded as Coal VII in this vicinity, will serve to explain this approximation of the Buchtel ore to the Great Vein of coal.

§ 90. An ore-seam at this horizon is persistent through a great part of the Hocking-Valley coal-field, and is frequently followed by another seam which lies between it and Coal VII, as will be shown farther on. What is considered by Read as the Buchtel ore is found in the upper Sunday Creek valley, in section 9 of Monroe, from seventy-five to eighty feet above Coal VI, and is by him described as a compact nodular ore, which in four openings measured from fifteen to thirty-six inches, and seemed abundant in the vicinity.

An ore occupying the same apparent position is met with in the lower Sunday Creek valley, according to different measurements, from fifteen to twenty-five feet below the Bayley's Run, or No. VII coal. In the Blonden shaft, already mentioned as sunk in fraction 36 of Trimble (§ 52), it was found seventeen feet below the coal, three feet in thickness, and resting on four feet of limestone. In section 15 of Trimble it is seen in the bed of the stream with a thickness of thirty-three inches, the limestone, as before, being beneath the ore.

§ 91. This ore, in the notation adopted by Prof. Read for the ores of the lower Sunday Creek valley, is No. 2. (Geol. of Ohio, vol. III., page 687.) His No. 3 is represented by about a foot of nodular ore in the shales immediately below Coal VII; while his No. 4 consists of several bands of nodules found in ten feet of shales just above this coal, the volume of ore at the points opened being estimated to be equal to two or three feet. It is exposed in numerous localities in Trimble and Dover. A single sample of this ore gave 33·0 per cent. of iron. Where seen by me in section 17 of Trimble, the layers extended through several feet of soft shales, and would yield a large amount of ore.

§ 92. At this locality the ore-bearing shales were overlaid by a heavy sand-rock, forming a cliff, immediately above which is the ore No. 5 of Read, called by Weethee the Great

Vein ore, from its thickness, which is, in places, five feet. One specimen of this ore, according to him, yielded 42·0 per cent., and the average of several analyses was 35·0 per cent. of iron. It is found at this horizon, which is from twenty-five to thirty feet above the Bayley's Run coal, in a great many places throughout Trimble and Dover, where various exposures show from two and a half to five feet of the ore. Prof Read says of it: "Its very numerous and heavy outcrops indicate that it may be found at this horizon throughout nearly the whole valley. It consists of layers of nodules or blocks, some of them so large as to require blasting. There can be little doubt that this fine bed of ore is continuous through all the hills in this neighborhood, and of sufficient thickness to be mined by drifting. The ore rests on a fine white clay, and is bedded in a red ferruginous clay, which extends up to a thin seam of coal five or ten feet above the ore, and is generally so compact as to constitute a good roof." (Geol. Ohio, vol. III., p. 688.)

§ 93. At a road-cutting called the Dugway, north of the town-site of Ewing, in section 7 of Trimble, this deposit is said to present five feet of ore, while the five feet of red shales above are filled with nodules of rich ore. I also saw it lately adjoining the Blonden shaft, nearly five feet thick, where it was a calcareous ore, a single sample of which yielded in the raw state 22·0 per cent. of iron. It was again seen on Johnson's Run in the north-west corner of section 24 of Trimble, and at various points along the course of the stream, with thicknesses of from two to four feet. At Hartleyville, near the mouth of the run, it appeared as a blue calcareous ore three feet thick, and gave me 33·6 per cent. of iron. From the locality first mentioned in section 17 of Trimble, it was also seen in various exposures for a distance of about three miles to the westward.

§ 94. The coal-seam noticed as occurring just above the last-mentioned ore is the so-called Splint coal, VII*a*

(§ 58), and with this in the lower Sunday Creek valley is associated the ore No. 6 of Read, which rests directly upon the coal. In fraction 1 of Trimble it is described as a calcareous ore three feet thick, yielding from 29·0 to 33·0 per cent. of iron; while at the Dugway already noticed it takes the form of a lean black-band ore from two to four feet in thickness. This ore, though varying in quantity and in quality, is, according to Read, found nearly everywhere in its place, above his No. 5; and he remarks that "the amount of ore bears an inverse ratio to the amount of the underlying coal."

§ 95. What we have regarded as the Buchtel ore (§ 90) resting on four feet of limestone, and lying twenty feet below the Coal VII, is, as we have seen, the lowest ore-stratum seen in the lower Sunday Creek valley. Read, in his description, however, assuming the existence of the Baird ore beneath, called this No. 1, and made the Buchtel ore No. 2. It will, however, be more simple and more convenient to follow Weethee in making the last-mentioned seam the starting-point in describing the ores of this valley. We thus have Nos. 1 and 2 below Coal VII, and Nos. 3, 4, and 5 between it and the Cambridge limestone, No. 5 apparently occupying the same horizon as Coal VII*a*; while above the Cambridge limestone are various ores designated by Weethee as Nos. 6 — 13, to be noticed farther on. These numbers, which we shall adopt in the following pages, are, of course, only provisional.

§ 96. Recent observations have shown me that several of these ore-horizons of the lower Sunday Creek valley may be traced into the more western parts of the coal-field, where they have not hitherto been recognized.

It has already been mentioned that an impure ferruginous limestone accompanies the Buchtel ore. Thus, while samples of the uncalcined carbonate ore mined for the Lee furnace, on the Cawthorn land, yield from 28·0 to 36·0 per cent. of

iron, the stratum immediately overlying it, and locally known as the Boulder bed, from its nodular character, is a limestone holding from 16·0 to 13·0 per cent. of iron, and even less. An outcrop seen at this horizon may, therefore, afford either good ore or a ferruginous limestone, and some practice is required to enable one to distinguish between the two. We shall now proceed to notice some facts with regard to the distribution of the Buchtel ore, and its association in many localities with what should apparently be regarded as the representative of Weethee's ore No. 2.

§ 97. Beginning in the north-west corner of section 6 of Waterloo, the Buchtel seam was seen in its place about twenty feet below Coal VII, — which is mined near by, with a thickness of nearly four feet, — and about twelve feet above the Buff limestone. There is here a considerable thickness of what was regarded as ore, but a single specimen taken from this locality proved to be but an impure ferruginous limestone. What was considered to be the same ore was seen in section 13 of York, and also in fraction 1 of York, in several places in the valley of Floodwood Creek, and apparently in good quantity. It was again met with in section 8 of York, while on the opposite side of the Hocking River, in section 3 of York, on the land of the Buchtel Iron Co., the same ore has lately been opened, with a thickness varying from one to three feet. Its position here is found by Col. Riley to be from eighty to eighty-five feet above the base of Coal VII, the Buff limestone being sixty-five feet above the same horizon. From one of these openings, where the deposit was two feet or more in thickness, I took fragments from one mass of limonite which gave me 38·0 per cent. of iron, while the average from two others was 30·6 per cent.; an accompanying calcareous block gave only 14·6 per cent.

§ 98. The Buchtel ore was seen with unusual thickness in the south-west corner of section 37 of York, on the land of W. W. Poston; while a few feet above it, and just below

the sandstone which marks the horizon of Coal VII (not here exposed), was a large pile of ore from an opening made some years since. This ore was said by Mr. Poston to have been not less than five feet in thickness. It was a reddish, porous limonite ore, but was laminated in its structure, and gave, for an average specimen, 37·8 per cent. of iron. This deposit, from its position, was conjectured to represent Weethee's ore No. 2.

On section 23, adjoining this last, to the west, on the land of Charles Robbins, the two ores just described were again seen, the upper, as before, although weathered to a limonite, being somewhat laminated or schistose in structure. Just above the latter was seen, near by, an outcrop of Coal VII, and over it a heavy sand-rock.

§ 99. On the land of Mr. Swackhammer, in section 33 of Ward, was found a similar ore-horizon above the Buchtel seam, there exposed, both being in good quantity; the upper seam here, as in the localities just mentioned in York, being apparently the richer of the two. There are found in this locality ten or twelve feet of good fire-clay beneath the lower ore. To the eastward of the last, on the Cawthorn land, section 7 of Ward, late explorations have shown the existence of an ore-horizon fourteen feet above the top of the Buchtel seam, and seven feet below Coal VII, described as good kidney-ore in shales.

§ 100. According to notes furnished me, the Buchtel ore is found in its regular position in the eastern part of Starr, in sections 4, 9, 13 and 5, and in fraction 5. A similar report is made of the lands in Brown, on sections 13 to 18, from north to south through the township, and also of fractions 25 and 32 and section 6.

§ 101. There has been opened on the lands of Peter Hayden, in the south-east corner of Green, a remarkable deposit, locally known as the Hayden ore, which, according to Andrews, occupies the horizon of the Buchtel seam. Its

position is said by him to be eighty-seven feet above the base of Coal VI, and twenty-two feet above a limestone three feet in thickness; a little below which is a black shale, with a thin seam of coal, regarded by Andrews as VI*b*. There are several openings of this ore. In one hill it is described as from one to four feet in thickness, and in another, as twenty inches, the ore, in both cases, being red and earthy in texture; besides which, nodules of ore are found in the shales above. In a third opening, the deposit is described as a nodular red ore, imbedded in fire-clay, with a thin layer of limestone above. There is, apparently, a large amount of this red ore in the vicinity. Two analyses of the Hayden ore show over 20·0 per cent. of carbonate of lime with a little magnesia, and from 43·0 to 44·0 per cent. of peroxyd of iron (equal to about 31·0 per cent. of iron), with very little combined water; so that it appears to be essentially a calcareous earthy red hematite. Other samples are said to be richer in iron. Some observers have been disposed to assign these isolated and outlying deposits of ore to a horizon above the Buchtel seam, where, however, the measurements given by Andrews would seem to fix its place.

§ 102. Passing now to the ores above Coal VII, I found, in the north-east corner of section 18 of Waterloo, on the land of J. Garber, above a heavy sand-rock, which there overlies the coal just named, a considerable mass of ore, in part a red peroxydized but calcareous mass, which gave me 33·2 per cent. of iron, while a portion of coarsely crystalline calcareous rock immediately associated with it yielded only 10·0 per cent. of iron. The whole mass here exposed was not less than five feet in thickness; but it remains to be determined how much of this is rich ore. The same deposit was again seen a few hundred feet farther. Its position was estimated at from twenty-five to thirty feet above Coal VII,

and it was overlaid by several feet of reddish clay, the Cambridge limestone being seen not far above.

A red peroxydized ore, calcareous like the last, and, like it, overlying the heavy sandstone, was also seen, with a thickness of three feet, in section 13 of York, and yielded me 34·9 per cent. of iron.

§ 103. An ore in a similar position is reported to me as lying, in great nodular masses, thirty feet above Coal VII, in section 29 of Dover, on the land of Daniel Fulton, and as having yielded 42·0 per cent. of iron. Again, in section 31 of Dover, I am informed that two beds of ore have been opened, at estimated distances of ten and thirty feet above Coal VII, which is there four feet thick. These are described as red block ores, each several feet in thickness. These two may correspond to ores 3 and 4 of Weethee, to the latter of which would perhaps belong the red ores noticed in § 102.

§ 104. On the land of Thos. Allen, in fraction 25 of York, I found exposed, on Lewis's Branch, four feet or more of nodular ore, in shales. One of the masses gave me 34·6 of iron, while the other was an impure limestone, holding only 12·8 per cent. of iron. The position of this ore was, at the time, estimated at about twenty feet above what was regarded as Coal VII. A few feet higher were seen large blocks of a reddish limonite ore, along an unopened outcrop, which yielded 40·0 per cent. of iron.

A massive carbonate ore, two or three feet thick, on the land of Mr. Blackburn, in section 32 of York, which was supposed to be at the same horizon with the lower ore just noticed on Lewis's Branch, gave me 31·2 per cent. of iron.

§ 105. A little farther, in the same direction, on the land of W. C. Campbell, in the adjacent southern portions of sectons 2 and 8 of Starr, there was seen, in a ravine, a great mass of weathered ore, brown and concretionary, which, as near as could be measured, was not less than

twelve feet. A single specimen of limonite ore from this outcrop gave me 39·7 per cent. of iron, while another specimen, from a second outcrop on the same land, proved a ferruginous limestone, with but 15·5 per cent. of iron. The position of these ores was estimated, at the time, to be from thirty to forty feet above Coal VII. In all of the localities in Starr, and thence southward through the central parts of Brown in which we have indicated the presence of the Cambridge limestone (§ 70), the notes of exploration furnished me indicate the existence of a similar ore-horizon between what is regarded as Coal VII and the limestone; a reddish earth or clay always appearing between the ore and the overlying limestone. A sample of a reddish calcareous ore from this horizon, in section 16 of Brown, gave me 27·8 per cent. of iron.

§ 106. These various outcrops of ore which I have noticed in York (as well as those reported in Starr and Brown), require farther openings and examination, as well as careful levellings, to determine the real position of many of them in the geological series. The thickness of these outcrops is, doubtless, sometimes above the average, for the reason that it is the thicker parts of an ore-deposit which attract the attention of explorers and prospectors, and which are naturally selected for opening. In some cases, also, I have seen an ore-bed exposed in the bank of a stream by a slip of the strata, which gave to the deposit an exaggerated appearance of thickness. The twelve feet of ore mentioned in § 105 afford, perhaps, an instance of the kind.

§ 107. We have next to notice what is known as the Iron Point or the Shawnee ore, which is extensively mined at Iron Point, in section 10 of Salt Lick township, immediately to the north-east of Shawnee. The position of this ore has been variously stated as from 91 to 110 feet above Coal VI, the variations being apparently due to irregularities in the intervening strata, since, according to Mr. J. H. Lyons, the

interval is found to differ as much as ten feet in a distance of six rods. The ore, which forms a solid bed, laminated in structure and with vertical joints, is a fine-grained and nearly pure carbonate of iron. It is intimately associated with a deposit of coal, which sometimes forms thin layers or plates interleaved with the mass of ore, and at other times is found resting either below or above the ore, which in parts is free from any coaly admixture.

§ 108. The deposit varies from one foot to four feet, and probably averages two feet in thickness. In one section thirty-nine inches of ore were found resting on three inches of the coal, which is occasionally thicker and for short distances sometimes wholly replaces the ore. From its frequent intermixture with coal, it has been called a black-band ore, though in the ores which elsewhere are known as black-band, the carbonaceous matter is generally diffused through the mass, rather than distinctly interlaminated as is the case in the Iron Point ore. This deposit has now been opened at many points over an area of several hundred acres, and yields an ore of great value, which for some years has furnished the chief supply to four blast-furnaces in and near Shawnee. It gives, after calcination, over 50·0 per cent. of iron.

§ 109. Explorations in search of this ore have been made on the property of the Straitsville Cannel-Coal Company, in sections 14 and 23 of Salt Lick, a little to the south-east of Shawnee, where several shafts were sunk under the direction of Mr. J. H. Lyons, the superintendent of the above company, with results which are reported by Andrews. One of these shafts showed the Bayley's Run Coal, VII, with a thickness of four feet ten inches, separated by eighty-two feet from the summit of Coal VI, which, taking the thickness of this last at ten feet, would make an interval of ninety-two feet from the base of VI to that of VII. Forty-four feet above the latter is a seam of six inches of

coal, representing VII*a*. The section showing these coal-seams and their associated ores is as follows:

*Section near Shawnee.*

| Feet. | |
|---|---|
| 136. | Coal VII*a*; six inches. |
| 109. | Shale with some ore; twenty-seven feet. |
| 107½. | Blue ore; eighteen inches. |
| 103½. | Sandstone; four feet. |
| 102. | Blue ore; eighteen inches. |
| 97. | Shale with nodular ore; five feet. |
| 92. | Coal VII; four feet ten inches. |
| 0. | Coal VI (assumed to be ten feet). |

§ 110. In another shaft 30″ of carbonate ore were found twenty-six feet below VII*a* (which thin coal-seam is everywhere found in the vicinity), the intervening shales including considerable ore in the form of nodules. In a third shaft the same carbonate ore — here twenty-nine feet below the uppermost coal — measures 24″, with 17″ of nodular ore beneath. The records of these shafts, as preserved by Andrews, give no details of the interval between Coals VI and VII; but at Shawnee, the limestone which take its name from this locality is found, with a thickness of two feet or more, sixty feet above Coal VI. I was moreover informed by the superintendent of the Iron Point Mining Company, that there was found, at three points, in sinking to a depth of fifteen feet below the black-band, about two feet of bluish carbonate ore, specimens of which, seen by me after calcination, seemed of good quality.

§ 111. Andrews supposes with Lyons, that the blue carbonate ore found by the latter five feet above Coal VII, though very different in aspect, may be the equivalent of the Iron Point ore. It is however to be considered that in the above section Coal VII is found with its full thickness, while at Iron Point it is wanting, or rather is represented only by the coal which accompanies the black-band ore. We have

here, then, an example of the more or less complete replacement of a coal-seam by a deposit of carbonate of iron, similar to that already noticed for Coal V, as described in § 83, § 84, and for Coal VII*a* in § 94. If, then, the Iron Point black-band results from a local deposition of iron-ore in the place of Coal VII, the ores found between this coal and VII*a* in the sections south-east of Shawnee, would correspond to those designated by Weethee, in the lower Sunday Creek valley, as Nos. 3 and 4; while the carbonate met with beneath the deposit at Iron Point would be the Buchtel ore.

It would follow, moreover, that the ore which, in Orton's section of the series on Meeker's Run, given on page 19, he has called the Iron Point ore, must be the equivalent of one of the higher ores, probably No. 4.

§ 112. There has lately been found near the Helen furnace, in sections 1 and 7 of Ward, an ore which resembles closely in its characters that of Iron Point, being a fine-grained, massive carbonate ore, with thin interposed leaves of coal, which is immediately overlaid by about eighteen inches of solid coal, succeeded by shales. The ore, which is underlaid by three or four feet of fire-clay, is from 10″ to 24″ inches in thickness, and like that of Iron Point is a very pure carbonate, yielding after calcination more than 50·0 per cent. of iron. It was found to be ninety-three feet above the base of Coal VI, and it thus occupies the position of Coal VII, which would appear to be represented here, as at Iron Point, by the coal accompanying the ore. Some distance beneath it is a seam of two feet of coal, supposed to be VI*b*, a buff limestone being found in the interval; while between the ore and the overlying Cambridge limestone is the blossom of another seam of coal, probably VII*a*. This ore, which has been traced along an outcrop of a mile or more, and is already mined to a considerable extent, promises, like its probable equivalent near Shawnee, to be of great economic importance.

§ 113. It remains to notice some important deposits of ore which are found in the more northern parts of the coal-field, belonging to several different horizons below the Cambridge limestone. I am informed that the Iron Point ore, with its peculiar characters, and from one to three feet in thickness, is traced from Iron Point, in section 10 of Salt Lick, as far as McCuneville, a mile more to the east, where considerable quantities of the ore have been mined for the Licking Iron Company of Shawnee. This company has also mined ore near Dixon station, in section 31 of Pike, two miles north of McCuneville, and gets from Crossenville, farther west, in section 30 of Jackson, a supply of the block ores from below the Baird ore. Some of these lower ores to the north-west of New Lexington, have been extensively mined for the Zanesville blast-furnace. The Baird ore, with its usual thickness, is found at its proper horizon in this vicinity, and according to Read, considerable quantities of good ore are also found here in the shales both just below and above Coal VI.

§ 114. "About forty feet above the Great Vein at Moxahala station," says Read, "a remarkably fine ore has been opened, called there the Norris-coal ore, because it was believed to be near the horizon of that coal. I would suggest for it the name of the Moxahala ore. It is in large, massive nodules, the seven feet of shales exposed disclosing the equivalent of from four to five feet of solid ore, in part a brown oxyd, and inpart a blue carbonate. . . . The dark ore yields by analysis 41·6 per cent. of iron, and the blue ore 25·0 per cent., the latter containing lime enough for a flux."

It was found by drifting at this point that the ore had here fallen much below its true horizon, which is, according to Read, just above the Shawnee limestone, being identical with what we have already called the Straitsville ore. The same is, according to him, found in section 10 of Pike, at sixty-five feet above Coal VI, where it is exposed with a thick-

ness of a foot, as a compact nodular peroxydized ore of superior quality, resting on a fire-clay. The limestone has here at some points been found just below the ore (§ 88).

§ 115. As regards the higher ore-seams in this neighborhood, there has been made at Moxahala, according to Read, "an opening in a stratum 116 feet above the Great Vein [Coal VI] which shows a large quantity of good ore in small nodules, mingled with nodules of calcareous ore. . . . About fifteen feet above it is a limestone from one and a half to two feet thick, of good quality. . . . This ore I regard as the equivalent of Prof. Andrews's Latta ore, which he places fifteen feet above the Stallsmith coal [VII]. It is found in nodules or blocks, sometimes two feet in thickness, and he traces it through all the hills of this region." This ore, a limonite from the Latta farm, south of New Lexington, is said to yield 41·3 per cent. of iron.

§ 116. A little to the north-west of Moxahala, in section 14 of Pike, on the top of a hill, there is found over an area of a little less than two acres, a deposit of ore known as the Hone bank, which is from seven to eight feet in thickness. The position of this is, according to Andrews, reported to be, by measurement, a little over 100 feet above Coal VI. "The ore rests upon a sand-rock, and no coal is seen below it. In this region the Bayley's Run coal is generally absent." This ore, which is covered only by a few feet of clay, is a very pure limonite, yielding an average of 55·7 per cent. of iron. "There is little appearance of lamination, and no traces of carbonaceous matter were detected." It is nevertheless supposed by Andrews to belong to the horizon of the Iron Point ore. To this is also referred a deposit on the Whitlock land, in section 16 of Bearfield, the extent of which has not been determined. It is laminated in structure, with occasional films of coal, and under cover is said to present the characters of a black-band ore. It yields, when calcined, over 50·0 per

cent. of iron. Considerable masses of nodular ore overlie, in some parts, this laminated deposit of black-band.

§ 117. Some ten miles farther to the west, near Bristol, which is in section 30 of Pike, there are found considerable areas of ore which have been referred to the same horizon as the last. These areas, already proved by borings, would, according to Andrews, "make an aggregate of from 150 to 200 acres in which the ore is believed to range from two to thirteen feet in thickness." It is conjectured that the ore under cover would prove to be a black-band, but no evidence is cited in support of this view. The analysis of an average sample of the partially peroxydized ore, got by borings in the mass, gives 33·8 per cent. of iron, 20·0 per cent. of silica, and 4·0 per cent. of lime and magnesia; which is very unlike that of the various black-band ores of the region, and more like the blue silicious and calcareous carbonate ores.

According to Andrews, Mr. Chamberlin of the Moxahala Iron Company, "estimates the stratigraphical position of this ore to be from twenty to twenty-five feet above the Bayley's Run coal, which he says is well developed in the neighborhood of the ore." When it is remembered that at the Hone bank, as well as at Iron Point, and near the Helen furnace, the black-band ore seems to replace the Bayley's Run coal, we are strengthened in the opinion that the large deposits of ore in the vicinity of Bristol are to be referred, like those disclosed in the shafts near Shawnee (§ 111), to a higher horizon than the Iron Point ore.

§ 118. It still remains to consider the iron-ores which in the Hocking Valley coal-field are found above the Cambridge limestone. These have been more especially studied by Weethee, whose observations have been to a great extent confirmed by Read, Andrews, and others. We have seen that in Weethee's notation, the highest ore below the Cambridge limestone is No. 5. This limestone itself is more or less ferruginous, and in sections 12 and 30 of Dover, openings have

disclosed, resting upon it, according to Weethee, a rich ore, well oxydized and from six to thirteen inches thick, besides which nodules of ore were found in the clays above. The ore of this horizon, which has not been farther explored, is designated by Weethee, No. 6.

§ 119. In section 24 of Dover, an opening seventy-three feet below the Ames limestone (and thus from forty to fifty above the Cambridge limestone), shows what is described as apparently a conglomerate or brecciated ore, consisting of hard blue carbonate, with an admixture of iron-oxyd. It is said to have the appearance of a rich ore and to be eighteen inches in thickness. This deposit is called No. 6*a*.

According to Mr. Daniel Fulton, an ore is found on the same horizon, seventy-two feet below the Ames limestone, in section 29 of Dover. A drift was here carried fifty feet into this ore-bed, which is described as a blue carbonate, the thickness of which is not given, yielding 32·0 per cent. of iron. It has immediately above it a seam of coal sometimes twenty inches thick, which is that already noticed in § 60, as Coal VIIc. This coal is seen with a thickness of eighteen inches on the eastern border of section 3 of York, about forty feet above the Cambridge limestone, and is underlaid at a distance of ten feet by a stratum of iron-ore, which may perhaps be regarded as No. 6*a*.

§ 120. About fifty feet below the Ames limestone another ore, designated as No. 7, is found on sections 11 and 12 of Dover, and on section 19 of Trimble, on Green's Run. It is called the Cave ore from the fact that it is usually found beneath a protecting sand-rock, and is described as massive, about two and a half feet thick, and, in some localities, apparently a rich ore.

§ 121. Ten feet above the last, or forty feet below the Ames limestone, is ore No. 8, which is thus described by Read. "It has been opened on section 19, and on fractions 1 and 36 of Trimble, and also on sections 30 and 33 of Dover.

In all the places now opened it is about two and a half feet thick, in small solid and closely packed nodules, and contains about 42·0 per cent. of iron. It is an ore of great promise, and appears to be present in large quantities." In fraction 18 of Trimble, on Laurel branch of Mud Fork, there is found, at thirty-five feet below the Ames limestone, and therefore substantially on the same horizon as No. 8, a massive conglomerate described as consisting of ore, with limestone, quartz pebbles, and fragments of fossilized wood.

§ 122. We come next to ore No. 9 of Weethee, called by him the Fulton ore, because opened on the land of Daniel Fulton, in section 29 of Dover. It is also exposed, according to him, in fraction 36 of Trimble, "and indications of its presence in many places may be observed." My recent inquiries with regard to this ore-horizon have been kindly answered by letters from Messrs. Read, Orton, Weethee, and Fulton. Its position is described by Read in his printed report, as "a few feet below the Ames limestone." Weethee in one locality makes it ten feet below, and according to Fulton its place is eighteen feet below this limestone, the blossom of a little seam of coal appearing just above the ore. Where seen by Mr. Read the Ames limestone was wanting; the opening on the Fulton farm, according to him, being "carried some fifty feet into the hill, but no cover reached." He adds, "the maximum thickness at places observed by me is eighteen inches; the nodules and fragments of ore, some of considerable size in the earth above, indicate a thicker stratum when the rock-cover is reached. . . . Prof. Weethee reports finding at one point a solid block of the ore, ten inches thick and one foot above the regular stratum, constituting no part of the latter, which measured at that place twenty-five inches. This makes the whole thickness of ore at that place thirty-five inches."

§ 123. As regards the nature of the Fulton ore, it is, in the report of Read, just quoted, called a peroxyd, and in

subsequent passages in the same report it is implied that the same ore is a hydrated peroxyd. The statements of Read and Weethee that it contains over sixty per cent. of iron, and the belief that it occupies the horizon where I have elsewhere found a red hematite or anhydrous peroxyd, led to inquiries by which I learn from Prof. Read that specimens from the opening already mentioned gave to Prof. Wormley 60·13 per cent. of iron and only 2·50 of water; the remainder being silica, with some manganese and earthy impurities. This composition indicates an essentially anhydrous peroxyd or red hematite ore. Other localities of a similar ore will be mentioned farther on.

§ 124. Above the Ames limestone, at fifteen feet according to Read, and twenty-one feet according to Weethee, is the ore called by the latter No. 10. It is described as consisting of two massive layers, each one foot thick, constituting a nearly solid mass of two feet, separating into large irregular blocks. The ore is said to be in parts a carbonate yielding from 30·0 to 34·0 per cent. of iron. The only locality of this ore mentioned is in section 30 of Dover. In the same section of Dover, Weethee describes as occurring at this horizon a peroxyd similar to the Fulton ore, and in a recent private communication he states that such an ore is found at this horizon in many places.

§ 125. Ore No. 11, from thirty-five to forty feet above the Ames limestone, is described as a nodular ore similar to No. 8, and in places two and a half feet thick, which is seen in section 30 of Dover, and farther east, in Ames township. In one opening in Dover, not farther indicated, there is said to be at this horizon from twenty to twenty-four inches of a peroxyd resembling the Fulton ore.

§ 126. Ore No. 12, which, like the last, is said to be found on the Davis farm, in section 30 of Dover, is described as lying about eighty feet above the Ames limestone, and as also resembling the Fulton ore.

Ore No. 13 is said to be found from twenty to fifty feet below the Pittsburgh coal, to consist of hard brown nodules scattered through thirty feet of ferruginous clay, and yielding 55·3 per cent. of iron. No details are given as to the localities of this ore, which can only occur on the highest parts of the lands in the south-east portion of this coal-field.

§ 127. These notices of ores above the Cambridge limestone are to be regarded chiefly as guides in the farther exploration of the region. As well observed by Read — and the remark will apply to all the ores of the coal-field : — "While these ores are largely developed, and widely distributed, none of them are to be regarded as absolutely persistent. In places, massive sand-rocks, and in others shales, occupy the horizons of these ores, without any sign of their presence; the calcareous ores also sometimes pass into limestone, and outcrops of ores are frequently noticed which cannot be referred to any of the foregoing numbers." Thus, in section 30 of Dover, about fifty-five feet above the Ames limestone, there is found, according to him, an outcrop of a conglomerate-ore twelve feet thick. "In this immediate neighborhood forty feet of the shales above the Ames limestone are highly ferruginous, and bands of good ore are to be seen at so many elevations that their outcrops cannot be reduced to a system. The ore is, most of it, well oxydized, apparently rich, and like the Fulton ore, and there are places where it is probable that this whole thickness of forty feet will be worked for the ore." (Geology of Ohio, vol. III, pp. 687–692.)

§ 128. These higher ores of the lower Sunday Creek valley have not, for the most part, been traced beyond its limits, and from their position above the Cambridge limestone must necessarily have a limited distribution in the western parts of the field. I have, however, found a horizon of red hematite, apparently corresponding to the Fulton ore, or No. 9 of Weethee, to be widely spread over the higher

lands of the region. It was seen by me on the east side of the Snow Fork valley, near the eastern border of section 33 of Trimble, where its position was at the time estimated by me at about twenty feet below the Ames limestone, which is well displayed near by. The ore is found in nodules and masses, sometimes several pounds in weight, imbedded in a red earth, and was considered by General Hamilton, who has opened the deposit, to be equal to a layer of six inches or more.

§ 129. Farther to the south-west, in the north half of section 23 of Waterloo, on the land of Samuel Cagg, nodules of a similar ore, sometimes four inches in diameter, are found in some abundance in a reddish clay, and in sinking a pit a layer of them eighteen inches thick is said to have been found. The same ore is reported from sections 7, 9, and 13 of York, and I have seen several specimens from this vicinity, where its position is probably not far below the Ames limestone, which is seen on Perry's Ridge in section 13 of York.

§ 130. The same ore was seen by me in the south-east corner of section 8 of Starr, where it is scattered over the surface in some abundance, and was said to have been found as a layer of nodules six inches thick, in sinking a well. Fine specimens of the same ore have lately been brought to me from the land of S. G. Dunn, in section 16 of Brown; and the existence of the ore in this region was first made known to me by specimens received in 1874 from section 19 of Brown. It is reported to be found over all the high lands in the south-east part of this township.

Its position in Starr and in Brown appears to be, as in Trimble and York, not far below the Ames limestone, and it probably occupies the horizon of the Fulton ore. The ore from all of these localities is of a dark purplish-red, very heavy, so hard in parts as not to be scratched with a knife, and occasionally somewhat crystalline, though often fine-

grained. It is then susceptible of a fine polish, and constitutes a true blood-stone or compact hematite. With this hard ore are, however, found masses of a softer dark-red ore, apparently an earthy variety of the same species. This hard red hematite was known to the ancient people of the region, who fashioned from it their small wedge-shaped tools, called celts, specimens of which, made of hematite, are occasionally found in parts of south-eastern Ohio and West Virginia. Analyses of this valuable ore, which contains 60·0 per cent. or more of iron, will be given farther on.

§ 131. Prof. Orton informs me that he has found this ore in some abundance about six miles south of the town of Athens, near the line between the townships of Alexander and Lodi, at a horizon estimated at between thirty and fifty feet above the Ames limestone. It will be remembered that Weethee observed at this horizon, which is that of his No. 11, an ore which he compared to the Fulton ore. I noticed in my report of 1874, where the hematite from Brown was first described and analyzed, the presence of the same ore scattered over the surface, at Big Run in the township of Rome, some miles east of Athens, which would be above the Pittsburgh seam, and also mentioned nodules of the same ore, said to have been been found in sinking a shaft at Wellston, in Milton township, in Jackson County; where it was reported be about thirty feet above Coal I, and to be disseminated through two feet of shales.

§ 132. In the accompanying table is shown the succession of iron-ores, and their relations to the coals and limestones of the series. The approximate intervals in feet between these are given in the left-hand column, precisely as in the table on page 4, with, however, the addition of Coal VIIc. The Iron Point and the Helen black-band ores are represented as the equivalents of Coal VII, which, in the present state of our knowledge, seems the most probable view. A similar relation between Coal VII*a* and ore No. 5, and between

Coal V and one of the ores immediately above the Gray limestone, has been already pointed out by Read.

We have added to this table the limestones and ores below the Gray limestone, on account of their importance in connection with the coal-field. In the right-hand column the figures refer to the numbered sections in the preceding pages, so that by their aid the table is made to serve as an index to the descriptions of the various coals, limestones, and iron-ores of the series.

*General Section for the Hocking Valley.*

| | | |
|---|---|---|
| 480 | Coal VIII, Pittsburgh seam, | 5. |
| — | Ore No. 13, | 126. |
| — | Ore No. 12, | 126. |
| — | Ore No. 11, | 125. |
| — | Ore No. 10, | 124. |
| 350 | Ames limestone, | 71. |
| — | Ore No. 9; Hematite, | 122, 128–131. |
| — | Ore No. 8, | 121. |
| 300 | Coal VII*c*, | 60, 119. |
| — | Ore No. 7, | 120. |
| — | Ore No. 6*a*, | 119. |
| — | Ore No. 6, | 118. |
| 230 | Cambridge limestone, | 69. |
| 180 | Coal VII*a*=Ore No. 5, | 58, 59, 94. |
| — | Ore No. 4, | 92, 102–105, 110. |
| — | Ore No. 3, | 91, 103, 110, 117. |
| 140 | Coal VII=Iron Point ore, | 48, 107, 111–117. |
| — | Ore No. 2, | 91, 98, 99. |
| — | Buchtel ore, (No. 1,) and limestone, | 68, 89, 96–101. |
| 120 | Shawnee limestone and Straitsville ore, | 66, 88, 114. |
| 100 | Coal VI*b*, | 33, 39. |
| — | Norris limestone and ore, | 67, 87. |
| 80 | Coal VI*a*, | 33. |
| — | Snow-Fork limestone; with ore, | 67, 86. |
| 50 | Coal VI; Great Vein, | 9. |
| — | Snow-Fork ore, | 85. |
| 10 | Coal V; with ore, | 8, 83, 84. |
| — | Baird or Limestone-ore, | 81, 83, 84, 113. |
| 0 | Gray or Ferriferous limestone, | 65. |
| — | Block ores, | 78, 79, 80, 82. |
| — | Blue or Zoar limestone, | 64. |
| — | White or Maxville limestone, | 64. |

## COALS AND COAL-MINING.

§ 133. Having discussed in previous pages the facts known as to the geology and the geographical distribution of the coals, iron-ores, and limestones of the Hocking Valley, we proceed to examine them in their economic relations. We shall first consider the coals as to their qualities, their chemical composition, their adaptation to various uses, their exploitation, and their commercial importance. After this we shall discuss the iron-ores and limestones as regards their composition, the mining of them, and their value for smelting, to which will be added a brief account of the manufacture of iron in the Hocking Valley.

§ 134. The coal-mining in this region has been, with small exceptions, confined to Coal VI, or the so-called Great Vein, which, from its thickness, its purity, and its adaptability to various uses, is the characteristic coal of the field, and in the markets of the north and west is known as the Hocking-Valley or Hocking coal, and is farther distinguished as Straitsville, Shawnee, Haydenville, Nelsonville, Monday Creek and Sunday Creek or Corning coal, from the localities in which it is mined.

The Hocking coal belongs to the class known as dry, free-burning or non-caking coals, which do not soften and run together in burning. These coals are very distinct from those which become soft and agglutinate when heated; the latter are prized for blacksmiths' use, as they make what is called a hollow fire, and are also much valued for generating steam, especially on the Ohio steamboats, where the draught in the furnaces is so strong that an adhesive coal is preferred. Certain varieties of free-burning coals, mined in northern Ohio and the adjacent parts of Pennsylvania, and also in a small area in Indiana, are locally known by the name of block coals from the readiness with which, from the presence of joints at right angles to the bed, they break

into rectangular blocks. These coals are laminated in structure, and are seen to be made up of thin alternate layers of a bright and shining coal, with others which are less lustrous. They often split readily in the direction of these layers, which are parallel to the bedding of the coal, and have their surfaces covered with a soft, black, fibrous substance known as mineral charcoal. On the other hand, it is difficult to break them across the layers, and when broken in this direction, as well described by Prof. E. T. Cox in his account of the block coals of Indiana, they "exhibit a splinty fracture, marked by alternate layers of dull and of shining black coal." For this reason, apparently, the name of splint coal is given to this class of coals in Scotland. Their aspect is very different from that of fat caking coals, which generally break irregularly, with broad, smooth and shining surfaces, although some coking coals are laminated.

§ 135. The Hocking coal from the Great Vein is like those just described, laminated in structure, with the characters of a splint coal, and breaks, for the most part, into large firm blocks. It burns with a bright flame and swells slightly, but, instead of forming a coherent mass, breaks up, and gives a body of glowing coals, which resemble those produced in the combustion of wood. It has occasionally been spoken of as a cannel coal, but it is hardly necessary to say that it differs from cannel, not only in its structure and its lustre, but in containing much less volatile matter and much more fixed carbon, which give it a greater heating power than cannel. For household purposes it is perhaps best burned in deep grates, such as are used for anthracite.

§ 136. One of the most important applications of dry-burning or splint coal is for the manufacture of iron in the blast-furnace. The ordinary bituminous or caking coals cannot be used in the raw state for iron-smelting, but require to be first made into coke; while the dry or non-caking

coals, provided they are sufficiently hard and strong to bear, without crushing, the burden of the furnace, may be used directly, like anthracite. The block coals mentioned above are largely used for this purpose in the Chenango Valley in Mercer Co., Pennsylvania, and also in the Mahoning Valley in north-eastern Ohio, in both of which districts are large numbers of furnaces for smelting the rich iron-ores of Lake Superior. This coal from near Youngstown in the Mahoning Valley, known in the markets as Briar Hill coal, is also used for this purpose at Cleveland, and at Newburgh in its vicinity, where the Lake Superior ores are smelted by its aid and yield an iron used for the manufacture of Bessemer steel. The iron-industry of the various districts just named is based on the employment of these block coals, which are used either alone or with an admixture of coke. The experience of the last few years has shown that the dry-burning coal of the Hocking Valley is equally well fitted for this purpose and, as will be seen farther on, its consumption for this use alone in this coal-field, and its immediate vicinity, equals 350,000 tons for the year 1880.

§ 137. We have now to consider the chemical composition of the coal of the Great Vein, as shown by the numerous analyses of Prof. T. G. Wormley of the University of Pennsylvania, late chemist to the Geological Survey of Ohio. Some of these are to be found in the reports of the survey for 1869 and 1870, and a few later ones in the official report for 1873, and in two special reports by Prof. Andrews, also published in 1873. The greater number of these analyses are given below, but in some cases I have contented myself with giving the average of several. From a description given by Prof. Wormley in the report for 1870, we learn that the analyses were made as follows: the loss of weight in drying a portion of the powdered coal at 212° F. is regarded as water, and the loss by heating another portion of the coal to redness, out of contact of air, being ascertained,

this, less the amount of water, is set down as combustible volatile matter; while the solid residue, less the weight of the ash left by complete combustion, is the fixed carbon. The weight of the coke may be got from the tables by adding together the ash and the fixed carbon.

§ 138. The determinations of the amount of sulphur in coals are very important. We shall find given under this head, in many of the analyses below, first, the total amount of sulphur in 100 parts of the coal; second, the amount of this which remains fixed in the coke; and third, the quantity of sulphur which 100 parts of the coke will contain, marked "Sulphur, per cent. in coke." The color of the ash and the texture of the coke are also in most cases given. The amount of iron in the ash, as shown by its more or less red color, is generally supposed to be an indication of the proportion of sulphur in a coal, it being imagined that the sulphur exists in combination with iron, as pyrites. That such is not always the case, had already been in some instances shown, but Prof. Wormley has pointed out many examples of this. He determined in certain coals both the sulphur and the iron present, and in the case of coal No. 10, in Table II., found the iron to amount to 0·38 parts, sufficient to combine with only 0·43, or less than one-third of the 1·42 parts of sulphur; while coal No. 12 of the same table contains only 0·09 of iron and 1·01 of sulphur.

§ 139. In some cases nearly the whole of the sulphur is given off at a red heat, while in other cases the greater part of it is retained in the coke; a distinction of much importance. For gas-making, those coals which retain the greatest amount of sulphur will yield the purest gas, while for iron-smelting, on the contrary, those coals which give off by heat the greater part of their sulphur are to be preferred; since, even when used in their raw state, this ingredient is expelled in the upper part of the furnace, so that the coke, which, lower

down, effects the reduction and the melting of the iron, is comparatively free from sulphur.

§ 140. The following tables of analyses show the variations in composition from the bottom to the top of the Great Vein, and also the diversities in various localities. Table I. includes the analyses of coals from Nelsonville in York, and Haydenville in Green. In both of these the coal is from 6′ 0″ to 6′ 6″ in thickness, and is divided, as elsewhere, by two thin clay partings, into three benches. The lowest of these measures from 1′ 3″ to 1′ 7″, the middle from 2′ 4″ to 2′ 5″, and the upper from 2′ 0″ to 2′ 4″. Nos. 1–4 are from Brooks's mine at Nelsonville. 1 is an average sample of the coal; 2, the coal of the lower; 3, that of the middle; and 4, that of the upper bench. Nos. 5–7 are from Hayden's mine, at Haydenville; 5, being from the lower, 6, from the middle, and 7, from the upper bench. In both cases it will be seen that the upper part contains the most ash.

*I. Coals from Nelsonville and Haydenville.*

| | No. 1. | No. 2. | No. 3. | No. 4. | No. 5. | No. 6. | No. 7. |
|---|---|---|---|---|---|---|---|
| Specific gravity, . | 1.259 | 1.285 | 1.272 | 1.284 | 1.271 | 1.258 | 1.340 |
| Water, . . . | 6.80 | 6.20 | 6.65 | 5.00 | 6.45 | 5.30 | 5.45 |
| Volatile matter, . | 33.27 | 31.30 | 33.05 | 32.80 | 32.74 | 30.12 | 29.88 |
| Fixed carbon, . | 57.46 | 59.80 | 58.40 | 53.15 | 58.56 | 63.49 | 55.31 |
| Ash, . . . | 2.47 | 2.70 | 1.90 | 9.05 | 2.25 | 1.09 | 9.36 |
| | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| Sulphur, . . | 0.74 | 0.97 | 0.41 | 0.94 | 1.19 | 0.64 | 1.63 |
| Color of ash, . . | Dull white. | Reddish. | White. | Yellowish. gray. | Grayish. | White. | Reddish. |
| Nature of coke, . | Compact. | Pulverulent. | Pulverulent. | Pulverulent. | Pulverulent. | - | - |

§ 141. Going northward from Nelsonville about six miles, to Lost Run in section 24 of Ward, the Great Vein is found to have assumed a thickness of 10′, and we give below, in Table II., the results of six analyses of portions of the coal from this locality, taken at regular intervals from the bottom to the top of the seam, as before. It will be seen here, also, that the upper portions, Nos. 12 and 13, contain the most ash; while the lower eight feet, which, according to Andrews, are represented by Nos. 8–11, give but small amounts of ash.

*II. Coals from Lost Run in Ward.*

| | No. 8. | No. 9. | No. 10. | No. 11. | No. 12. | No. 13. |
|---|---|---|---|---|---|---|
| Specific gravity, . . . | 1.278 | 1.290 | 1.257 | 1.284 | 1.287 | 1.274 |
| Water, . . . . . | 7.15 | 6.80 | 5.85 | 6.15 | 5.80 | 3.05 |
| Volatile matter, . . . | 35.28 | 36.16 | 37.10 | 33.22 | 35.42 | 38.39 |
| Fixed carbon, . . . | 55.16 | 54.99 | 55.12 | 55.75 | 51.15 | 47.51 |
| Ash, . . . . . | 2.41 | 2.05 | 1.93 | 4.88 | 7.63 | 11.05 |
| | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| Sulphur, . . . . . | 1.35 | 1.07 | 1.42 | 1.88 | 1.01 | 4.04 |
| Sulphur left in coke, . . | 0.81 | 0.79 | 0.51 | 1.00 | 0.50 | 2.02 |
| Sulphur, per cent. in coke, . | 1.31 | 1.30 | 0.85 | 1.56 | 0.81 | 3.35 |
| Color of ash, . . . | Fawn. | Fawn. | Fawn. | Gray. | Cream. | Gray. |
| Nature of coke, . . | Compact. | Compact. | Compact. | Compact. | Very compact. | Very compact. |

§ 142. Farther north, at the McGinnis coal-bank at Straitsville, the Great Vein measures 11′, with two partings. The lowest bench is here 2′, the middle 1′ 8″, and the upper 6′ 10″; the partings being from 2″ to 4″ each. In Table III., Nos. 14 and 15 are from the lower bench, No. 16 from the middle bench, and Nos. 17, 18, and 19 respectively from the bottom, middle, and top of the upper bench.

### *III. Coals from Old Straitsville.*

| | No. 14. | No. 15. | No. 16. | No. 17. | No. 18. | No. 19. |
|---|---|---|---|---|---|---|
| Specific gravity, . . . | 1.291 | 1.241 | 1.239 | 1.307 | 1.247 | 1.248 |
| Water, . . . . . | 7.90 | 8.15 | 7.20 | 7.60 | 6.00 | 5.35 |
| Volatile matter, . . . | 34.63 | 27.46 | 32.29 | 29.65 | 32.15 | 30.48 |
| Fixed carbon, . . . | 54.29 | 61.73 | 59.44 | 52.77 | 59.41 | 57.21 |
| Ash, . . . . . | 3.18 | 2.66 | 1.07 | 9.98 | 2.44 | 6.96 |
| | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| Sulphur, . . . . . | 0.98 | 0.78 | 0.73 | 0.68 | 0.50 | 1.22 |
| Color of ash, . . . | Dull white. | Reddish. | Reddish. | White. | Yellowish gray. | Grayish. |
| Nature of coke, . . . | Compact. | – | Pulverulent. | Pulverulent. | Pulverulent. | Pulverulent. |

§ 143. From New Straitsville, where the seam has about the same thickness as at the last locality, we have four analyses of different portions of the seam from the bottom to the top. These are given in Table IV, under Nos. 20–23, counting from below upwards. Nos. 24 and 25, in the same table, are from the Benjamin Saunders coal-bank, in section 19 of Monroe. There, also, the vein is over 10′ thick, the lower bench being 3′, the middle 5′ 9″, and the upper bench 1′ 11″. Of this, two analyses are given, one of the middle bench, No. 24, and one of the upper bench, No. 25 (this latter had been deprived of its water by drying at 212° F. before analysis). Of the coal of the middle bench, here so remarkably developed, Prof. Andrews remarks, that it is highly laminated, especially in the lower 12″ and the upper 18″, charged with mineral charcoal and eminently fitted, from its large amount of fixed carbon, for iron-smelting.

*IV. Coals from New Straitsville and from Monroe.*

| | No. 20. | No. 21. | No. 22. | No. 23. | No. 24. | No. 25. |
|---|---|---|---|---|---|---|
| Specific gravity, . . . . . | 1.260 | 1.281 | 1.262 | 1.276 | 1.300 | - |
| Water, . . . . . | 7.70 | 7.40 | 7.20 | 5.30 | 5.60 | - |
| Volatile matter, . . . . . | 30.70 | 29.20 | 30.10 | 31.00 | 29.92 | 41.70 |
| Fixed carbon, . . . . . | 59.00 | 60.45 | 57.55 | 55.75 | 62.45 | 55.50 |
| Ash, . . . . . | 2.60 | 2.95 | 5.15 | 7.95 | 2.03 | 2.80 |
| | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| Sulphur, . . . . . | 0.49 | 0.93 | 0.57 | 1.18 | 0.76 | 2.56 |
| Sulphur left in coke, . . . . | 0.082 | 0.015 | 0.26 | 0.082 | - | - |
| Sulphur, per cent. in coke, . . . | 0.13 | 0.023 | 0.41 | 0.128 | - | - |

§ 144. Besides the last two, we have many more analyses of coals from the Great Vein in Monroe, on the waters of Sunday Creek. From these analyses we take a series of five from the Welsh bank, in section 8 of Monroe, where the seam measures 13′ 2″, from which only 4″ are to be deducted for the two clay partings. The lower bench is here 2′ 9″, and the middle 5′ 9″, while the upper is 3′ 11″, and here, as elsewhere in Monroe and Salt Lick, is somewhat like cannel in its aspect. In Table V, No. 26 is from the middle of the lower bench, Nos. 27–29 from the lower, middle and upper parts of the middle bench, and No. 30 from the middle of the upper bench. To these we add No. 31, the average of seven analyses from the bottom to the top of the Sands coal-bank, in section 9 of Monroe, which measures 11′ 3″. Deducting from these the analysis of the top portion, which gives 11.26 per cent. of ash, the average of ash would be much less than above given. No. 32, according to Andrews, gives the average of not less than twenty-seven analyses which have been made of the coal of the upper part of the Sunday Creek region, including those already given from No. 24.

*V. Coals from Various Parts of Monroe.*

| | No. 26. | No. 27. | No. 28. | No. 29. | No. 30. | No. 31. | No. 32. |
|---|---|---|---|---|---|---|---|
| Specific gravity, | 1.312 | 1.385 | 1.300 | 1.316 | 1.302 | 1.300 | - |
| Water, | 4.40 | 4.90 | 4.30 | 5.20 | 4.60 | 6.42 | 5.34 |
| Volatile matter, | 30.60 | 28.30 | 32.70 | 31.40 | 33.40 | 33.87 | 31.40 |
| Fixed carbon, | 62.30 | 53.50 | 58.80 | 58.40 | 57.30 | 54.17 | 58.17 |
| Ash, | 2.70 | 13.30 | 4.20 | 5.00 | 4.70 | 5.54 | 5.09 |
| | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| Sulphur, | 0.90 | 0.79 | 0.71 | 0.74 | 0.71 | 0.88 | 0.88 |
| Sulphur left in coke, | 0.43 | - | 0.35 | 0.38 | 0.35 | - | - |
| Color of ash, | Dull white. | Dull white. | Yellow. | Yellow. | Yellow. | - | - |
| Nature of coke, | Compact. | Pulverulent. | Compact. | Compact. | Compact. | - | - |

§ 145. For the lower part of Sunday Creek, where the Great Vein lies beneath the water-level, we have only a few analyses of the coal taken from recent borings. Three of these, Nos. 33–35 in Table VI, are on Green's Run and Bayley's Run, from the confines of Dover and Trimble, while a fourth, No. 36, is from section 7 in the latter township.

*VI. Coals from Borings in Dover and Trimble.*

| | No. 33. | No. 34. | No. 35. | No. 36. |
|---|---|---|---|---|
| Specific gravity, | - | - | - | 1.303 |
| Water, | 4.70 | 2.10 | 4.85 | 4.10 |
| Volatile matter, | 29.30 | 38.80 | 33.95 | 32.90 |
| Fixed carbon, | 56.00 | 52.90 | 52.80 | 57.50 |
| Ash, | 10.00 | 6.20 | 8.40 | 5.50 |
| | 100.00 | 100.00 | 100.00 | 100.00 |
| Sulphur, | 0.60 | 0.77 | 0.60 | 0.79 |
| Sulphur left in coke, | 0.054 | 0.22 | 0.21 | 0.49 |
| Sulphur, per cent. in coke, | 0.08 | 0.37 | 0.34 | 0.77 |
| Color of ash, | - | - | - | Dull white. |
| Nature of coke, | - | - | - | Compact. |

§ 146. We add in this connection, for comparison with the coal of the Great Vein of the Hocking-Valley field, some analyses of the similar dry-burning coals already referred to as mined in the Mahoning Valley in northern Ohio, and in Clay County, Indiana. No. 37 is a sample of Briar-Hill coal from Chestnut Ridge; No. 38 from Veatch's mine, Youngstown; No. 39 from Walworth's mine, Mahoning County; while No. 40 is the average of six analyses of the block coal from Trumbull County. No. 41 is of a sample of the block coal from Brazil, Clay County, Indiana; while No. 42 is the average of seven analyses of the same coal from six different mines in Clay County, the extremes in the amount of fixed carbon in these being 61·5 and 53·0. The analyses from which this average is made are given by Prof. E. T. Cox in the "Report of the Geological Survey of Indiana for 1869," and are incomplete, as they give us no indication of the proportion of sulphur present. The other analyses in this table are all by Prof. Wormley.

*VII. Block Coals of the Mahoning Valley and of Indiana.*

| | No. 37. | No. 38. | No. 39. | No. 40. | No. 41. | No. 42. |
|---|---|---|---|---|---|---|
| Specific gravity, . . . . . | 1.284 | 1.260 | 1.323 | – | 1.173 | 1.232 |
| Water, . . . . . | 3.60 | 2.47 | 3.90 | 3.65 | 5.46 | 6.10 |
| Volatile matter, . . . . . | 32.58 | 31.83 | 29.10 | 30.10 | 38.76 | 34.80 |
| Fixed carbon, . . . . . | 62.66 | 64.25 | 60.40 | 64.30 | 53.99 | 57.20 |
| Ash, . . . . . | 1.16 | 1.45 | 6.60 | 1.95 | 1.80 | 1.90 |
| | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| Sulphur, . . . . . | 0.85 | 0.56 | 0.82 | 1.02 | 0.75 | – |
| Sulphur in coke, . . . . . | – | 0.48 | 0.60 | 0.61 | – | – |
| Sulphur, per cent. in coke, . . . | – | – | – | 0.94 | – | – |

§ 147. The composition of the coals from the higher seams in the Hocking-Valley field has been less studied than that of the Great Vein. We have, however, a few analyses both of VI*b* and VII. Of the former, or Norris seam, No. 43 is a specimen analyzed by Prof. Wormley from section 9 of Monroe. No. 44 was collected by me in section 19 of York, and analyzed by Mr. Stafford; while No. 45 is a specimen, said to be of the Norris coal from the vicinity of Bessemer, analyzed by Dr. S. D. Hayes. He regarded it as a valuable gas-coal, and, according to a private communication to me, found it to yield an amount equal to 10,250 cubic feet of gas of high illuminating power to the ton of 2,000 pounds. I added to these, under No. 46, in Table VIII., the analysis by Wormley of a specimen of Coal VII, from the Stallsmith bank in section 30 of Monroe, which differs from the other analyses of this coal given farther on in Table IX. in containing a greater amount of volatile matter.

*VIII. Coals VIb and VII.*

| | No. 43. | No. 44. | No. 45. | No. 46. |
|---|---|---|---|---|
| Water, | 3.80 | 3.49 | 1.68 | 3.80 |
| Volatile matter, | 38.80 | 39.50 | 43.42 | 40.21 |
| Fixed carbon, | 52.80 | 51.85 | 45.99 | 51.85 |
| Ash, | 4.60 | 5.16 | 3.42 | 4.14 |
| | 100.00 | 100.00 | 99.51 | 100.00 |
| Sulphur, | 3.59 | 2.09 | 0.49 | 2.62 |

§ 148. In Table IX. are given the analyses by Prof. Wormley of several samples of the Bayley's Run or No. VII coal, from openings in Trimble and Dover in the lower

Sunday-Creek valley. Nos. 47 and 48 are from J. Rutter's bank, in section 10 of Dover, and represent the lower and middle portions of the seam; the upper portion gave 2.96 of sulphur and 3.40 of red ash. Nos. 49 and 50 are from R. Stover's bank in section 23 of Trimble, and are taken respectively from the lower and upper portions of the seam. No. 51 is from the Chappalear bank, in section 7 of Trimble, near the line of Dover; No. 52 is from Allen's bank on Mud Fork, in fraction 2 of Trimble, and No. 53 from Southerton's bank, in section 34 of Dover. (See § 55.)

*IX. Coal VII from Trimble and Dover.*

| | No. 47. | No. 48. | No. 49. | No. 50. | No. 51 | No. 52. | No. 53. |
|---|---|---|---|---|---|---|---|
| Specific gravity, . . . | 1.301 | 1.264 | - | - | - | - | - |
| Water, . . . . . | 5.00 | 4.80 | 4 30 | 4.50 | 3.60 | 3.40 | 4.20 |
| Volatile matter, . . . | 32.30 | 35.20 | 33.19 | 31.30 | 35.00 | 34.40 | 35.20 |
| Fixed carbon, . . . | 55.30 | 56.60 | 59.60 | 57.80 | 58.30 | 56.30 | 58.00 |
| Ash, . . . . . | 7.40 | 3.40 | 3.00 | 6.40 | 2.60 | 5.90 | 2.60 |
| | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| Sulphur, . . . . . | 1.85 | 1.20 | 1.20 | 1.15 | 1.29 | 1.09 | 1.04 |
| Sulphur in coke, . . | 0.42 | 0.69 | 0.46 | 0.52 | 0.49 | 0.60 | 0.41 |
| Sulphur, per cent. in coke, | - | - | 0.73 | 0.80 | 0.79 | 0.96 | 0.67 |
| Color of ash, . . . | Fawn. | Reddish. | Gray. | Whitish. | Gray. | Gray. | Gray. |

All of these coals were found to give a compact coke, and that from Nos. 49, 50, and 52 is described as being metallic in aspect.

§ 149. Other things being equal, those coals are most esteemed which contain the least sulphur. From the analyses already given of twenty-two specimens of the Great Vein from Nelsonville, Haydenville, Lost Run in Ward, and Old and New Straitsville (omitting No. 13, the ashy and

pyritous layer from the top of the seam), it appears that the average content of sulphur is 0·93 per cent.; while the average of the analyses of twenty-three specimens of the same coal from the upper Sunday Creek region, as calculated by Andrews, and stated under No. 32 in Table IV., gives 0·88 of sulphur. The average sulphur from four analyses of the same coal, got by borings in the lower Sunday Creek valley, as given in Table VI., is 0·69, while that from the seven analyses of Coal VII, in the same region, as seen in Table IX., is 1·26 per cent. of sulphur.

§ 150. The latter figure, though greater than for Coal VI, shows a less proportion of sulphur than is found in the coals of other parts of the State and those of other regions. According to the published analyses of Ohio coals by Prof. Wormley, the average amount of sulphur in seven samples of the coal mined at Cambridge, in Guernsey County, is 1·98 per cent.; that of nine from Coshocton County, 2·21; of nine from Stark County, 1·94; of ten from Holmes County, 2·15; and of seven from Columbia County, 1·95. Of the coals of Great Britain, as appears from an extended series of analyses made a few years since for the British Admiralty, the average amount of sulphur in thirty-seven Welsh coals was 1·42 per cent.; of twenty-eight from Lancashire, 1·42; of eight Scotch coals, 1·45; and of seventeen from Newcastle, 0·94. The coke of Durham, esteemed in England as the best fuel for iron-smelting, retains from 0·60 to 0·80 of sulphur, and the Connellsville coke about the same. The analysis by Mr. J. Blodgett Britton of an average sample of this coke, made up from forty-nine pieces, was as follows: carbon, 87·456; ash, 11·382; moisture, 0·490; sulphur, 0·693; phosphorus, 0·029 = 100·000. The ash contained 47·0 per cent. of silica, and 47·0 of alumina. From all these data it would appear that not only Coal VI, but Coal VII, and the coke made from it, contain less than the usual amount of sulphur.

§ 151. The greater part of the coals in Ohio to the northward of the Hocking-Valley field are unusually sulphurous, as appears from the analyses of forty-two samples from five northern counties, given above. In the words of Dr. Newberry, "with the exception of the Briar-Hill coal, there is probably no seam which, along its outcrop, north of the National Road [which extends from Wheeling on the Ohio to Columbus] can supply a first-class furnace-fuel." The other coals of this region are, he tells us, usually caking in character, and only fit for the furnace after coking. They generally, moreover, contain so large a quantity of sulphur that they cannot be used for gas-coals, and he adds: "It will be necessary that some process should be adopted for ridding our coals of the sulphur with which they are so generally contaminated, before they will become available for the most important uses." To this end, he suggests that a process of washing the crushed coal and coking it be resorted to, (Report of Geological Survey for 1870, pages 43–44). It is hardly necessary to remark that this large proportion of sulphur detracts greatly from their value for all other purposes for which coal is employed, such as generating steam, puddling iron, and household use.

§ 152. Some notice of the Briar-Hill coal, as the only fuel in Ohio to the north of the Hocking-Valley coal which can be compared with it, will not be out of place. This name is given to a splint or dry-burning coal, which is No. I of the series, and is found, with a thickness of from three to five feet, at the base of the coal-measures in portions of Mahoning, Trumbull, Columbiana, and the adjacent counties to the west. It lies in small irregular basins, which were deposited on an uneven floor, and are separated by wide intervals. Prof. M. C. Read states that the average of workable coal in the districts over which this coal is supposed to extend, will not exceed one-third of the area. An account of these irregularities will be found in his report on

Trumbull County (Geology of Ohio, vol. I., pages 494, 499). This coal is mined by shafts of from fifty to two hundred feet, and from the large amount of water in the mines the cost of extraction is considerably augmented.

§ 153. We have already mentioned (§ 134) the similar dry-burning block coal, which within the last few years has been mined in the western part of Indiana, on the eastern border of the Illinois coal-basin and, as a fuel for iron-smelting, is probably equal to the coal of the Mahoning Valley. It is, however, like this last, irregular in its distribution and interrupted by frequent intervals of barren ground. At Brazil, in Clay County, which is the part of the field as yet best known, there are two seams of block coal, twenty-eight feet apart, and from three to four feet in thickness. The lower, being the firmer of the two, is preferred for iron-smelting. According to Mr. Eilers, who has carefully examined the district, the chief drawback to the successful working of this field "is the great irregularity of the seams, which, in some parts of the field are often wanting entirely, or are so interrupted by horse-backs that mining becomes too expensive to be profitable. Nothing but great numbers of bore-holes, put down before mining in a given tract is commenced, can assure the miner in this field that his land actually contains the coal." Notwithstanding the apparent regularity of the strata as a whole, "one or more coal-veins may be present in full size on one farm, while in the adjoining one not a trace of either may exist."* Analyses of these dry-burning coals of the Mahoning Valley and of Indiana have been already given. (§ 146.)

§ 154. We have now given a description of the Hocking Valley coal-field, and of the nature of its coals, especially of the Great Vein, and have, moreover, furnished the means of comparing this with some of the other coals of the West

* A. Eilers in "The Engineering and Mining Journal," Jan. 31, 1874.

which, in quality, may compete with it. In the case of those of the Mahoning Valley and of Indiana, we have seen that their mining is effected under disadvantageous conditions; the irregularities of the seams, their thinness and, in the first region, the presence of water, unite to augment their cost. If we look to the Hocking Valley we shall find, on the contrary, all the conditions favorable to the cheap and profitable extraction of its coal. Over by far the larger part of this field of 250 square miles the coal of the Great Vein lies above water-level, while the higher coals are everywhere so. With the exception of a few points in the south-eastern part of the field the coal is everywhere got by drifting, which, if done against the dip, affords a ready drainage. From the nature of the country, however, the surface-drainage is such that the mines are always dry. The thickness of the seam, from six feet upwards, is such as to allow great ease in working, and there is no expenditure necessary for cutting away the floor, as in thinner seams. The roof of the Great Vein is a strong slate, and the rooms in mining the coal near Nelsonville are opened with a breadth of thirty and even thirty-five feet. The country, moreover, abounds in forest-trees, and excellent hard wood for timbering the mines may be had on the land for the cost of cutting. The regularity of the floor, which is hard and dry, and the absence of rolls or undulations, are also noticeable; while, with the few exceptions already noticed, the Great Vein appears to be very regular and continuous in its development.

§ 155. The cost of opening a mine under these conditions is very small, since neither pumps nor hoisting-engines are necessary, although in many cases it will probably be found more advantageous to shaft for the coal and, after raising it to the hill-tops, to allow it to descend by gravity, than to draw it out over tramways for long distances to openings in the valleys. This method becomes necessary in the

southern and eastern portions of the field. The Great Vein has been opened by shafts at several points in south-eastern York and south-western Dover, and more recently farther north in the Sunday Creek valley, where, throughout Dover and Trimble, it can only be got by sinking.

§ 156. In estimating the yield of these mines, it will be well to give some data familiar to mining-engineers, which serve as the basis of calculations. The specific gravity of coal may be taken at 1·25, or one and a quarter times that of water, and a layer of such coal one foot in thickness will contain in an acre of superficies (4,840 square yards), 1,519 tons of 2,240 pounds, or 1,690 tons of 2,000 pounds of coal. It is to be noted that, while along the seaboard coal is sold by the ton of twenty hundred-weight the ton, to the west of tide-water in the United States, is reckoned at 2,000 pounds. The bushel is often estimated to contain eighty pounds, twenty-five bushels making a ton; but the average weight of a bushel of most coals is less, and at Pittsburgh is counted at seventy-six pounds, or nearly twenty-six and a half bushels to the ton, at which rate the miners, who work by the bushel, are paid. At Cincinnati, a ton of Pittsburgh coal is supposed to measure twenty-eight bushels, while a ton of Hocking-Valley coal, at Columbus, is reckoned at twenty-seven bushels.

§ 157. The actual yield of coal in working a vein varies greatly. Thus, in the anthracite mines of Pennsylvania, according to Mr. P. W. Sheafer, not more than one-third of the vein is got out in the condition of merchantable coal, while in the Mahoning Valley, the loss is estimated by Col. Whittlesey to be over one-third; so that, from a vein of three feet in that region, 3,000 tons of coal to an acre is considered a good return. Much better results than this are got by judicious working in favorable ground, and Warrington Smyth estimates that in Great Britain, on an average, about 80 per cent. of the coal is extracted. This, in case of long-

wall mining, is of course exceeded; while in some other mines the loss is much greater. In the extensive workings of Mr. Brooks, near Nelsonville, in the Hocking Valley, where the Great Vein (deducting the partings) gives six feet of coal, I am informed that his returns are at the rate of 7,200 tons per acre — equal to 1,200 tons of 2,000 pounds for each foot in thickness of coal. This, which is for merchantable coal (excluding nut-coal and slack), must be pronounced a fair result; though, under the exceptionably favorable conditions offered by the Great Vein, there is no doubt that more skillful mining would increase this large production.

§ 158. By far the greater part of the coal mined in the Hocking Valley is from the Great Vein. That of the upper seams — VI*b* and VII — is, however, mined to some extent for local purposes, and the latter seam is generally used throughout the lower Sunday Creek valley, from which region it was extracted and shipped, in a small way, by the Hocking and Ohio Rivers to Cincinnati, more than half a century since. Within a year, the seam which we have referred to as VI*b*, in Happy Hollow in north-eastern York, (§ 38) has been mined for shipment on a considerable scale, and yields a fuel much esteemed in the markets. At the same time, a portion of the coal there mined (including the slack or fine coal) has been successfully coked.

The Carbondale and Mineral City coals, which we have regarded as probably VI*b* (§§ 42, 43), are also largely mined for consumption along the line of the M. & C. R. R.; and within the last year especially, the Carbondale coal has been carried in large quantities to Cincinnati.

§ 159. The question of coking the coals of the upper seams is one of great importance for this region. Trials on a small scale have shown that the coals of both of these are capable of yielding a coke; but the only practical trial as yet made is that at Happy Hollow, just mentioned, where, in May last, there were in operation thirteen coke-ovens, yielding about

twenty tons daily of what seemed to be an excellent coke. The works have since been extended, and the coke has been employed for some days at the Akron blast-furnace at Bessemer, in place of the raw coal there used for smelting, and, as I am assured, with very satisfactory results, Mr. Buchtel, the president of the Akron Company, from comparative experiments, concluding that it was equal to the coke of Connellsville.

Mr. Buchtel has since tried, in the ovens at Happy Hollow, the coking of the coal from his upper seam, VII, which we have noticed in § 37, and, having found it to yield a satisfactory coke, proposes to build a large number of ovens for the production of coke from this seam.

The experience of American iron-smelters is more and more in favor of employing coke for iron-smelting, as being a fuel preferable either to raw coal or to anthracite; and many of the blast-furnaces in northern Ohio are now using with the raw coal of the Mahoning Valley a large admixture of coke.

§ 160. This application of coke is, however, important to the miners and iron-smelters of the Hocking Valley from another point of view. The desirableness of utilizing the coking coals of this region has from the first suggested itself to those interested in its development, not only on account of its intrinsic advantages, but as a means of economizing the precious coal of the Great Vein. Mr. John B. Pearse, who has paid much attention to this region, declares that the proper plan will be to mine the Great Vein for exportation, and to depend chiefly, if not entirely, for iron-smelting upon coke made from the upper coals.

§ 161. We have seen that there are found within less than one hundred feet above Coal VI, one, and, in some places, two workable seams of coal, the aggregate production of which, in some areas, would be nearly equal to that of the Great Vein below. The removal of this would, in

many cases, result in the breaking-down of the overlying strata, as a consequence of which the upper coals would be crushed, and their extraction rendered impossible. Hence, as Mr. Pearse suggests, a true economy would dictate the mining of the coal from the upper seams either before or at the same time with that of the Great Vein. The coal of the latter finds a ready sale in the markets of the north and west, while the coke which would be made from the upper seams would serve for the smelting of iron and the subsequent working of the metal, or would itself find a ready sale in the same markets.

§ 162. It has long been known that the deterioration which bituminous coals undergo by exposure to the air affects their capacity of softening and cementing by heat, so that some coals, which, when freshly mined, yield a coherent coke, after a little exposure to the air lose the property of doing so. Mr. James Macfarlane, the experienced author of "*The Coal Fields of North America*," has lately called attention to the fact that the complete unwatering or draining of a coal-seam, by permitting the access of air to the coal, gradually brings about a similar result; so that a coal-seam which, when mined under ordinary conditions is well fitted for blacksmiths' use, or for the production of a firm coke, often loses, when thus drained, the quality of softening or cohering by heat.* In this way the upper seams of the Hocking Valley field, even if not broken and disturbed by the extraction of the Great Vein below them, would become deteriorated in quality and unfitted for coking, in consequence of the draining and aëration of them which would result from its removal.

§ 163. The importance of a good coking coal is well shown by the example of the coke which is made at Connells-

* Mr. Macfarlane's paper on this subject, which I have been been permitted to read and to mention, will soon be published.

ville in south-western Pennsylvania, from the coal of the great Pittsburgh seam. This is here from nine to twelve feet in thickness, and is mined very cheaply, since there is no object in getting out large coal, the whole product being coked. This coal yields about sixty-five per cent. of coke, 100 bushels of it producing 125 bushels of coke weighing forty pounds to the bushel. The coke, an analysis of which has been given (§ 150), is brought fifty-five miles by rail to Pittsburgh, where it is largely consumed in iron-smelting and in other industries, and is also shipped to other markets. The Connellsville coke, from its great density and its acknowledged excellence, supplies to a large extent the markets of the West, going as far as Chicago and St. Louis, and even to the mining regions of the Rocky Mountains, where, however, it is now being replaced by coke made from coals found in parts of Colorado and Utah.

§ 164. The plan of crushing and washing impure coals previous to coking, by which they are freed from a large proportion of their sulphur and ash, and made to yield a purer coke, is one which is practised on a large scale in European countries, and though unnecessary in our better coals, like that of Connellsville, has been introduced with success in many large coke-works in western Pennsylvania, as well as at the Johnstown and Broad Top iron-furnaces. The cost of the operation is small, and the results are very satisfactory, since by its aid a superior coke for iron-smelting can be made even from inferior coals.

§ 165. In this place should be mentioned an important consideration connected with the dry-burning coal of the Great Vein, which, unlike the slack or finely broken coal of the upper seams, cannot be made to yield a coherent coke, and hence accumulates in great quantities at the mines, and is at present a waste product. Successful attempts have been made in Europe to consolidate such waste coal by mingling it with a portion of crushed or ground caking coal,

and coking the mixture. In this way, the whole is cemented together into a firm, coherent coke, and a great economy is effected. Some cementing coals suffice to bind together their own weight, and others two or three times as much of the slack or refuse of non-caking coal. The proximity in the Hocking Valley of the caking coals to the dry coal of the Great Vein, will enable this method to be there adopted with advantage; and the present large waste of the latter in the form of slack may thus be prevented.

§ 166. The coal of the Great Vein, as mined in the various parts of the Hocking Valley, from its comparatively large proportion of fixed carbon, its relative freedom from sulphur, its non-caking character, and its solidity and firmness,— which render it less liable than many other coals to break or crumble in handling,— has come to be highly esteemed not only for iron-smelting and for local use, but for transportation to the markets of the North and West. It is largely used as a steam-coal on the lakes, and also on the railways, and finds an increasing market in Ontario. I have lately been assured by the mechanical superintendent of the Chicago division of the Grand Trunk Railway that the coals of the Hocking Valley are now largely used for the locomotives on that line, and are found to be equal for the generation of steam to the Briar-Hill coal, and superior to any others known in the western markets.

§ 167. The Hocking coal from the vicinity of Straitsville is also employed as a gas-coal in Columbus, Lancaster and Newark, Ohio, where it has, for many years past, replaced the Youghiogheny coal of Pennsylvania, formerly used for the purpose. According to a report of the superintendent of the Columbus gas-works, the gas made from the latter was equal in illuminating power to fourteen candles, while that from the Straitsville coal was eighteen. This agrees closely with the photometric determinations of Prof. Wormley, the former State inspector of gas, who gives from seventeen to

nineteen candles. According to one statement, two thousand pounds of this coal yield eight thousand feet of purified gas, but it is stated in a report by Mr. W. Robbins, president of the Newark Gas Company, that the result of a trial of over eight tons of the coal from New Straitsville showed a product of nine thousand cubic feet to the ton of two thousand pounds. In ease of working, the coal compares favorably with cannel, giving off its gas at a moderate heat, while the coke is of superior quality.

§ 168. The high esteem in which the Hocking coal is held is best shown by the rapidly increasing demand for it, as will appear from the following figures. Previous to 1869, the date at which the Columbus and Hocking Valley R. R. was opened, the only communication with the coal-field, except by the Marietta & Cincinnati R. R., along its southern border, was by the canal; which then extended from Columbus to Athens, along the Hocking Valley, but is now closed below Nelsonville. In 1870, the new railroad brought to Columbus 50,000 tons; in 1871, 250,000 tons; in 1872, 600,000 tons; and in 1873, 801,000 tons of coal, mined in the Hocking Valley field. A second road, the Newark, Somerset and Straitsville R. R., was opened to Shawnee in 1872, and in 1873 there were shipped over it from this field 350,000 tons of coal, chiefly to the lake-ports. A little was also at that time taken from Carbondale and its vicinity by the M. &. C. R. R.; but the whole output of coal from this field in 1873 did not probably exceed 1,200,000 tons.

The great depression which from that date affected all the business interests of the country, retarded considerably the development of the coal-trade in this region, though, as we shall see, it did not prevent a great activity in the construction of iron-furnaces, to which attention about this time became directed.

§ 169. In 1877, however, the coal-trade began to recover from the depression, and the amount of coal transported over

the C. & H. V. R. R. rose to 800,975 tons, being about the same as in 1873. In 1878 it was 914,000 tons, and in 1879 attained to 1,108,972 tons. This amount was divided among the different stations as follows, as appears from the official report of the road: —

| Stations. | Tons. |
|---|---|
| Straitsville, | 525,684 |
| Gore, | 9,950 |
| Haydensville, | 62,653 |
| Lick Run, | 29,480 |
| Nelsonville, | 310,315 |
| Buchtel, | 47,065 |
| Monday Creek, | 55,524 |
| Carbon Hill, | 51,871 |
| Floodwood, | 7,533 |
| Salina, | 8,717 |
| Total, | 1,108,792 |

§ 170. The fiscal year of the road ends December 31, and the largely increased coal-traffic over it in 1880 can only be approximately determined. I am permitted by General Samuel Thomas of Columbus, Ohio, to publish the following estimate by him for the total production of coal from the Hocking Valley field for 1880, the figures being confessedly approximations. The amounts carried over the various railroads and the canal, and otherwise consumed, are by him given below.

| | | |
|---|---|---|
| Columbus and Hocking Valley R. R., | | 1,500,000 |
| Newark, Somerset & Straitsville R. R., | | 350,000 |
| Ohio Central R. R., | | 250,000 |
| Muskingum Valley R. R., | | 150,000 |
| Marietta and Cincinnati R. R., | | 150,000 |
| Hocking Valley Canal, | | 50,000 |
| | | 2,450,000 |
| Coal consumed in blast-furnaces | | 350,000 |
| Total, | | 2,800,000 |

§ 170 A. The significance of these figures will be better seen when we compare them with the entire coal-production of the United States. The amount of anthracite marketed in 1872 was 19,669,778 tons, and rose in 1873 to 21,227,922 tons. The depressed state of trade which followed caused a falling-off in the production of anthracite, which reached a minimum of 17,605,262 in 1878, but rose again in 1879 to not less 26,142,689 tons. The production for 1880 shows, for the period from January 1 to December 4, a falling-off of a little over two and a half million tons; so that the entire production for 1880 will be about 23,500,000 tons. This lessened demand is probably to be ascribed to the mild winter of 1879–1880, conjoined with an overproduction in 1879. The above figures represent the shipments from the mines, and thus do not include the coal consumed and sold at the mines, which is equal to about six per cent. of the entire output.

§ 171. The total estimated production of coal for the United States in 1879 was, according to the figures given by Saward in his valuable manual entitled "*The Coal Trade*," 59,808,398 tons from which, if we deduct 26,142,689 tons of anthracite, we have 33,665,709 tons for the production of bituminous (and semi-bituminous) coal, including that used for the making of coke. Of this quantity, 14,500,000 tons, in round numbers, are assigned to Pennsylvania, besides the whole of the anthracite. The production of Ohio comes next, being estimated, for the year 1879, at 5,000,000 tons. It is, however, rapidly increasing; the official returns for the twelve months ending May 31, 1880, being 6,397,725 tons. The output of Ohio for the present year, ending Dec. 31, 1880, is estimated by Mr. Andrew Roy, the State Inspector of Mines, at about 7,000,000 tons, with a probable increase to 8,500,000 tons for the year 1881. Notwithstanding the decreased production of anthracite, there is reason to believe that the total output of non-anthracitic

coals for the United States in 1880 will show a considerable increase over that of 1879.

§ 172. Coke is not made for exportation to any considerable extent, except in western Pennsylvania. The amount carried over the railroads in that region from Jan. 1 to Nov. 21, 1880, is given as 1,666,667 tons, that for the last week of the time being 44,280 tons. We may therefore assume, for the year, about 2,000,000 tons of coke, equal to about 3,000,000 tons of coal. Of the above 1,666,667 tons, 988,876 tons, or nearly three-fifths, came from the Connellsville region. The figures do not include the large amounts of coke made in various places for local consumption in blast-furnaces.

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## IRON-ORES AND IRON-MINING.

§ 173. The native iron-ores of the Hocking Valley, are for the most part carbonate of iron, or the limonite resulting from its alteration. These carbonates, as already described, (§ 73) are generally intermingled with more or less earthy matter, chiefly clay, with some sand, so that both the unaltered carbonates or siderites, known as blue or gray ores, and the limonites derived from them, often called brown ores, contain in most cases a considerable quantity of clay, and must be regarded as argillaceous ores.

For our present purpose we shall group together the carbonate and limonite ores of the principal horizons, and shall give analyses to show their average composition. In bringing together in one view the results of analyses made of the carbonates and limonites in their raw state, and of calcined ores, which may often have been admixtures of the two, it becomes necessary to adopt some general plan which will

enable us to tabulate these results. A farther difficulty arises from the fact that some of the analysts have calculated the iron of a carbonate ore as carbonate, others as protoxyd, and others still as metallic iron only; while the lime and magnesia are sometimes represented by them as uncombined, and sometimes as carbonates. For the purpose of comparing such varying analyses, we have thought best to give the iron as metallic iron, and to represent the lime and magnesia as uncombined. These, with the manganese, the silica, the alumina, (where determined), and the phosphorus and sulphur, give the elements necessary for the purposes of the metallurgist. The loss by calcination of the raw ores is also given, when known. This, in the carbonate ores corresponds essentially to the carbonic acid, with the addition of the organic matter in the case of the black-band; while in the limonites it represents the water.

We shall notice in the first place the more silicious ores, including the Baird, the Buchtel and some other ores, and next the black-band ores of Iron Point and of the Helen furnace. The chemical composition of the red hematite ores of the region will then be noticed. We shall next consider the methods and the cost of mining these ores, and lastly, as an appendix, give analyses of some of the limestones which are or may be used as fluxes in the blast-furnaces of the region.

§ 174. The composition of the Baird ore, as mined and smelted in the Hocking Valley, may be seen from the following analyses: Nos. 1 and 2, calcined ore for the Crafts Iron Co., (Britton); No. 3, calcined ore from the Gore furnace, (unknown); No. 4, raw ore, carbonate, from an outcrop on the land of Mr. Brooks, near Nelsonville, (Howard).

From the few analyses accessible, it appears that the block ores below the Baird ore closely resemble this in their proportion of iron and their general constitution. See analysis No. 17, page 100.

## *I. The Baird or Limestone Ore.*

| | No. 1. | No. 2. | No. 3. | No. 4. |
|---|---|---|---|---|
| Silicious matter, | 12.31 | 8.64 | 21.64 | 11.58 |
| Alumina, | 7.02 | 2.78 | 2.35 | 1.78 |
| Lime, | 2.64 | 0.09 | – | 4.47 |
| Magnesia, | – | – | – | 1.23 |
| Oxyd of manganese, | 0.86 | 0.69 | 1.00 | 1.55 |
| Sulphur, | – | 0.09 | 0.26 | 0.54 |
| Phosphorus, | 0.29 | 0.06 | | 0.27 |
| Carbonic acid, | – | – | – | 28.86 |
| Water, | – | – | 4.05 | 2.43 |
| Metallic iron, | 42.45 | 53.24 | 46.80 | 35.37 |

§ 175. The Buchtel resembles the Baird ore, but is somewhat more silicious and less rich in iron, as will be seen by the following analyses: No. 5, limonite from outcrop at the Akron furnace, calcined, (Howard); No. 6, a similar ore from the Helen furnace, calcined, (Britton); No. 7, carbonate from Helen furnace, calcined, (Britton); No. 8, carbonate from Akron furnace, raw, (Britton); No. 9, carbonate from Helen furnace, raw, (Dickinson); No. 10, the so-called Boulder or upper layer of the Buchtel seam from the Helen furnace, an impure limestone, (Dickinson); No. 11, another specimen of the same, (Britton); No. 12, limonite, said to be an average from the ore-pile at the Helen (then the Ogden) furnace, in 1878; No. 13, average of the calcined carbonate ore, smelted at the same furnace in February and March, 1880, (Britton); No. 14, average of a car-load of calcined carbonate ore from the Cawthorn land, used at the Lee furnace in 1879, (Dickinson).

*II. Ores from the Buchtel Seam.*

| | No. 5. | No. 6. | No. 7. | No. 8. | No. 9. |
|---|---|---|---|---|---|
| Silicious matter, | 28.31 | 15.58 | 12.24 | 19.01 | 12.52 |
| Alumina, | 1.32 | – | – | 2.20 | 5.27 |
| Lime, | 11.06 | 9.33 | 19.63 | 6.03 | 9.60 |
| Magnesia, | .84 | – | – | – | 2.95 |
| Oxyd of manganese, | 1.69 | – | – | – | – |
| Sulphur, | .37 | – | – | – | .29 |
| Phosphorus, | .34 | .14 | .58 | .36 | .69 |
| Loss by calcination, | – | – | – | – | 25.69 |
| Metallic iron, | 33.16 | 36.57 | 36.24 | 28.62 | 29.68 |

*III. Ores from the Buchtel Seam.*

| | No. 10. | No. 11. | No. 12. | No. 13. | No. 14. |
|---|---|---|---|---|---|
| Silicious matter, | 15.05 | 21.29 | 36.45 | 24.54 | 16.35 |
| Alumina, | 7.83 | – | – | 8.89 | 8.36 |
| Lime, | 21.19 | 24.53 | – | 10.43 | 13.87 |
| Magnesia, | 1.69 | – | – | – | – |
| Oxyd of manganese, | – | – | – | – | .60 |
| Sulphur, | .10 | – | .06 | – | .69 |
| Phosphorus, | .47 | .42 | .48 | 1.48 | 2.02 |
| Loss by calcination, | 27.50 | – | 10.70 | – | 3.75 |
| Metallic iron, | 16.40 | 13.42 | 35.35 | 30.82 | 32.50 |

§ 177. We give under Nos. 15–21 analyses of several other ores. Of these, Nos. 15 and 16 of the red ore from Peter Hayden's, already noticed in § 101, which would seem to be essentially a mixture of earthy anhydrous peroxyd or

red hematite with silicious matter and a large proportion of carbonate of lime. In reproducing these analyses we have disregarded the small amount of lime represented by Wormley as united with phosphorus in the form of phosphate of lime. Another sample of this ore, according to Andrews, gave by a partial analysis, "thirty-five per cent. of carbonates, with less silica and more iron" than the above.

*IV. Hayden's Red Ore.*

| | No. 15. | No. 16. |
|---|---|---|
| Silica, | 28.20 | 24.52 |
| Alumina, | 2.00 | 1.80 |
| Carbonate of lime, | 21.21 | 21.99 |
| Carbonate of magnesia, | .52 | 1.36 |
| Oxyd of manganese, | 1.00 | .75 |
| Sulphur, | .12 | .10 |
| Phosphorus, | .19 | 1.14 |
| Water, combined, | 3.00 | 1.70 |
| Metallic iron, | 30.56 | 31.00 |

§ 178. In the next table, V., No. 17, is the analysis by Wormley of the ore from Crossenville, mentioned in § 113 as mined by the Licking Iron Company, and one of the lower block ores. No. 18 is an analysis by Gregory of the Moxahala ore, noticed in § 114. No. 19, an analysis by Wormley of the Latta ore from near New Lexington, mentioned in § 115. No. 20 is from the large ore-bed near Bristol described in § 117; the analysis, by Gregory, having been made of the borings obtained in sinking holes to test the deposit. It would appear from the facts given that the ore was chiefly carbonate, but with some admixture of limonite. No. 21 is an analysis of an average sample made by

the writer from a number of the large concretionary masses of carbonate from the horizon described as that of the Snow Fork ore (§ 85), collected at an outcrop on Meeker's Run. This ore, when roasted, would yield 51·0 per cent. of iron. Another sample of the same ore from that vicinity was found by Wormley to be more impure, holding 18·8 per cent. of insoluble silicious matter and 21·5 per cent. of iron.

*V. Ores from Various Places.*

| | No. 17. | No. 18. | No. 19. | No. 20. | No. 21. |
|---|---|---|---|---|---|
| Silica, | 17.92 | 15.96 | 25.60 | 20.00 | 11.37 |
| Alumina, | – | – | 1.56 | – | 2.82 |
| Lime, | – | – | – | 4.00 | 3.56 |
| Magnesia, | – | – | – | – | 2.49 |
| Oxyd of manganese, | – | .42 | 2.40 | – | – |
| Sulphur, | – | – | – | – | – |
| Phosphorus, | .23 | .14 | – | .39 | .25 |
| Volatile matters, | 10.00 | – | 8.90 | – | 27.32 |
| Metallic iron, | 48.97 | 41.68 | 40.31 | 33.80 | 36.39 |

§ 179. We notice next the Iron Point ore, as mined at Shawnee (§107), and the similar ore described as occurring at the Hone and Whitlock banks in Pike and Bearfield (§ 116). No. 22 is an analysis of the raw carbonate ore from Shawnee, by Love; Nos. 23 and 24, of the same ore, calcined, by Gregory; No. 25 is of the Hone ore, said to be an average from a boring of seven feet, where there was but little covering; the ore has been changed into limonite. No. 26 is the carbonate ore from the Whitlock bank, said to hold 2·63 of organic matter and 3·80 of water. This should lose about one-third its weight by calcination, so that when roasted it would carry 55·0 per cent. of iron.

*VI. Iron Point Black-band, and Related Ores.*

| | No. 22. | No. 23. | No. 24. | No. 25. | No. 26. |
|---|---|---|---|---|---|
| Silica, | .59 | 10.60 | 2.43 | 4.42 | 2.73 |
| Alumina, | – | 1.14 | 8.30 | 1.16 | 4.82 |
| Lime, | 8.28 | – | 8.10 | .77 | 2.16 |
| Magnesia, | 3.80 | – | 1.82 | .14 | .90 |
| Oxyd of manganese, | 2.02 | 4.49 | 2.33 | 1.05 | 2.95 |
| Sulphur, | .10 | .13 | .39 | .07 | .52 |
| Phosphorus, | .70 | .24 | – | .45 | .37 |
| Volatile matter, | – | – | – | 10.61 | – |
| Metallic iron, | 43.58 | 52.26 | 52.67 | 55.71 | 36.96 |

§ 180. The newly discovered deposit of black-band near the Helen furnace in south-eastern Ward (§ 112) has been the subject of many careful analyses by Mr. H. Dickinson, chemist to the Hocking Iron Co., all of which the secretary of the company, Mr. Gilbert Attwood, has kindly furnished me. From them I select, as best calculated to give a notion of the composition of this valuable ore, the following analyses. No. 27, limonite from the outcrop of the bed; No. 28, carbonate, with interlaminated coal; No. 29, carbonate, hard, compact, gray, with black layers; No. 30, carbonate, black-band, showing a layer of small concretions; No. 31, average of 840 tons of the ore mined in June and July, 1880. There is found at the base of this deposit a thin, coaly and pyritous layer, which requires to be separated in mining. Its analysis gave: silica 54·19, alumina 8·97, iron 5·39, sulphur 5·97, and 29·33 of coaly matter to 100·00.

*VII. Helen Black-band Ore.*

| | No. 27. | No. 28. | No. 29. | No. 30. | No. 31. |
|---|---|---|---|---|---|
| Silica, | 1.55 | 1.52 | 8.16 | .82 | 4.93 |
| Alumina, | .50 | .62 | 2.91 | .65 | 2.51 |
| Lime, | 1.22 | 2.43 | 1.98 | 2.80 | 2.00 |
| Magnesia, | – | – | – | – | .68 |
| Oxyd of manganese, | 7.56 | 6.77 | 1.35 | 6.98 | 4.57 |
| Sulphur, | .03 | 2.38 | .37 | 1.00 | 1.07 |
| Phosphorus, | .77 | .36 | .22 | .34 | .87 |
| Volatile, | 16.50 | 38.00 | 35.60 | 36.40 | 28.30 |
| Metallic iron, | 46.01 | 31.25 | 33.53 | 33.74 | 36.43 |
| Do. in roasted ore, | 55.09 | 50.40 | 52.00 | 53.00 | 50.80 |

§ 181. It remains to give the results of several analyses, more or less complete, of the red hematite already noticed on pages 66–68. No. 32 is a sample from section 19 of Brown, described by me in 1874; its specific gravity was 4·475. No. 33 is from a sample made from three nodules collected by me in section 23 of Waterloo (§ 129) and kindly analyzed by Mr. J. Blodget Britton. No. 34 is of a portion of a single mass from the same locality, analyzed by Mr. H. Dickinson. No. 35, by the same, of the ore from section 8 of Starr (§ 130). All of the above were specimens of hard, compact hematite. No. 36 is an analysis by by Wormley of the Fulton ore (§ 122). No. 37, an analysis, by the same, of a red hematite ore from Washington County, Ohio, where it is found in nodules in the shales in the upper coal-measures, and, according to Andrews, has been collected for use in the puddling-furnaces at Marietta. (Geol. of Ohio, vol. II., pp. 479, 480, 483.) The specimen analyzed was from Maxburg, and had a specific gravity of 4·55.

*VIII. Red Hematite Ores.*

| | No. 32. | No. 33. | No. 34. | No. 35. | No. 36. | No. 37. |
|---|---|---|---|---|---|---|
| Silica, | - | 6.15 | - | - | 6.08 | 10.00 |
| Alumina, | - | - | - | - | 1.40 | 7.70 |
| Carbonate of lime, | - | - | - | - | 1.98 | - |
| Carbonate of magnesia, | - | - | - | - | .07 | - |
| Phosphorus, | - | .295 | .223 | .155 | .084 | - |
| Oxyd of manganese, | - | - | - | - | 1.90 | - |
| Peroxyd iron, | 87.15 | 87.60 | 89.29 | 84.81 | 85.90 | 78.58 |
| Volatile, | 2.00 | 1.88 | - | - | 2.50 | 1.20 |
| Metallic iron, | 61.00 | 61.33 | 62.50 | 59.37 | 60.13 | 55.00 |

§ 182. In the ordinary method of analyzing these argillaceous ores, they are attacked by chlorhydric acid. This, while dissolving the other elements, leaves behind with the silica the greater part of the alumina, of which only a small portion passes into solution. The insoluble residue from this treatment thus consists of silica with a variable amount of alumina. In the preceding analyses of iron ores, in tables I–III., the insoluble residue is given under the title of "Silicious matter." Of these, however, analyses Nos. 1, 2, 9, 10, 13 and 14 are probably complete, so that the "Silicious matter" is pure silica separated from the alumina, the full amount of which is also given. The same is probably true of all the analyses of the black-band ores, tables VI–VII, with the exception of No. 23. The excess of alumina in No. 24 suggests a possible error of some kind. The importance of determining the proportion of alumina and silica in all these cases will be made apparent farther on in considering the question of smelting these ores.

§ 183. In the account of the distribution of iron-ores in the region, on pages 46–66, will be found statements of the

amount of iron contained in ores from various localities and horizons besides those of which the analyses have just been given. Of these ores from undeveloped deposits, a considerable number, especially in the northern part of the field, and in the lower Sunday Creek valley, have been completely analyzed, but it is deemed sufficient for present purposes to give their percentage of iron. Their analyses, together with several already given in these pages, will be found in the Geology of Ohio, vol. III., pp. 677, 692, 693, and 711.

§ 184. The iron ores of this region, as we have already seen, lie in an almost horizontal position, dipping, except in a few exceptional localities, not more than from fifteen to thirty feet to the mile. This condition permits them to be mined to a large extent by what is called stripping; — that is to say, by stripping off the soil or soft clayey rock which covers the ore. It is evident that, by beginning at the outcrop of an ore-bed in a nearly level or gently sloping country, a large amount of ore may be got at by this plan. In the Hanging-Rock district, where great quantities of ores are mined under the conditions just described, it is found profitable to remove in this way from ten to fifteen feet of cover in order to get at the Baird or Limestone ore, which has there an average thickness of ten inches, (§ 81.) The price to be paid will vary with the thickness of the ore-seam, and the thickness and hardness of the overlying strata. When, from the nature of the cover, stripping is unprofitable, drifting is had recourse to. According to data furnished me in 1874, a layer of twelve inches of ore in the Hanging-Rock district was profitably mined by drifting, when in hard sandstone, and one of six inches in soft shales.

§ 185. In the autumn of 1880, the Buchtel seam was mined by contract on the lands of the Hocking Iron Co., in Ward, the price paid for the ore, which was got by stripping, being $1.00 per ton when the cover did not exceed ten feet, and $1.10 up to fifteen feet of cover. For the black-

band ore near the Helen furnace, the price was $1.25 up to twelve feet of cover. The miners at these rates furnish horses and tools, and deliver the ore on the banks, from which thirty-five cents a ton was paid for hauling the Buchtel ore to the Lee furnace, making its average cost there $1.50 the ton. The contractors were prepared to drift for the ores at the same rates of $1.10 and $1.25 per ton.

§ 186. The black-band ore of the Iron Point Mining Co. of Shawnee, which supplies in great part the four blast-furnaces of this place, is mined by the furnace-companies, who pay a royalty to the mining-company. The ore is got partly by stripping and partly by drifting.

The Licking Iron Co. of Shawnee, in 1877 and 1878 mined 44,000 tons of this ore, and has contracts to take for a term of years, not less than 15,000 tons yearly, at a royalty of forty cents per ton. Besides this supply from the Iron Point Mining Co., the Licking Iron Co. in the spring of 1880 were getting considerable quantities of ore from stations along the Newark, Somerset & Straitsville R. R., within five or six miles of Shawnee. This was in part mined by the company on their own or on leased lands, and in part bought from local proprietors, who mine and deliver the ore at sidings provided with scales for weighing the ore. For black-band ores thus mined the price paid at the station was $2.00, while for ores mined at Crossenville by the company, a royalty of thirty cents a ton was paid to the owners of the land.

§ 187. During the year 1880, considerable quantities of ores have been got along the line of the newly-opened Ohio & West Virginia R. R., chiefly in Swan and Starr townships. The amount received for eight months, up to September 1, was over 28,000 tons, of which 16,500 tons were of the lower block ores received at Carnsgrove station, the remainder being chiefly Baird ore. According to Mr. Walter Crafts of Columbus, to whom I am indebted for these figures, the average thickness of the Baird ore along the western border

of the Hocking Valley field, is from twelve to eighteen inches, rising, however, in places to three feet.

Some notion of the occasionally great yield of these ore-deposits may be got from the statement in the Geological Report of Ohio for 1870, that in section 22 of Elk, a little east of McArthur, 10,800 tons of ore were taken out from less than two acres, and that in another locality in this region three acres yielded 23,000 tons of ore.

§ 188. We have seen that a layer of coal of specific gravity 1·25, covering an acre one foot in thickness, will weigh 1,519 tons of 2,240 pounds. The mean specific gravity deduced from forty-two specimens of the carbonate ores of Ohio, by Dr. Wormley, was 3·37, which would give for a layer of one foot 4,087, or, in round numbers, 4,000 tons to the acre. This calculation agrees with the estimate which, according to Bauerman, is made for the Scotch black-band ores. These lose by calcination about one-half their weight, and are found to yield 2,000 tons of calcined ore, and 1,000 tons of pig-iron to the acre for each foot in thickness of ore. The richer ores of the Hocking Valley, weighing 4,000 tons to the acre, and yielding from 30 to 35 per cent. of iron in the raw state, would give from 1,200 to 1,400 tons of iron for each foot in thickness.

It has been shown (§ 77), that the carbonate ores in their change to limonite lose about one-fifth of their weight, and yield an ore which is proportionally more dense. As, however, this contraction shows itself in the porous or cavernous condition of the mass, it follows that a layer of such carbonate yielding 4,000 tons to the acre, would give 3,200 tons of an ore twenty per cent. richer than the carbonate from which it was derived, but having the same thickness, and yielding the same amount of iron to the acre as before.

§ 189. If we pass to the hematite ores, which, as we have seen, have a specific gravity of 4·5, and yield 60·0 per cent. or more of iron, we find that an acre of such ore one foot

thick would contain 5,468 tons, which, at 60 per cent., equals 3,284 tons of iron, or considerably more than twice as much as the same bulk of a carbonate yielding 35·0 per cent. It follows that a layer of red hematite which would yield equal to six inches of solid ore, would give more metallic iron than a layer of twelve inches of the best black-band ore of the region.

### *Limestones for Flux.*

§ 190. As to the limestones of this region, the White or Maxville limestone is quarried for use as a flux near Winona furnace in the vicinity, of Webb station, in the western part of the township of Gore. Orton cites five analyses of this limestone by Mr. C. C. Howard, of Columbus, as follows: No. 1, white variety, Winona-furnace drift; Nos. 2, 3, and 4, Culver and Stotler's, Webb Summit, representing respectively white, buff and blue varieties; No. 5, Glenford.

*I. Analyses of Maxville Limestone.*

| | No. 1. | No. 2 | No. 3. | No. 4. | No. 5. |
|---|---|---|---|---|---|
| Carbonate of lime, . . . . | 89.31 | 82.88 | 79.18 | 88.71 | 93.08 |
| Carbonate of magnesia, . . . | 1.52 | 2.23 | 1.96 | .54 | 1.59 |
| Oxyd of iron and alumina, . . . | 2.99 | 2.68 | 16.09 | 1.18 | 1.60 |
| Silicious matter, . . . . . | 5.91 | 11.58 | 4.28 | 9.01 | 3.02 |
| Total, . . . . . | 99.63 | 99.37 | 99.51 | 99.44 | 99.69 |

§ 191. No analyses of the Blue or the Gray limestone of this region are known to me, though limestones from both of these horizons are used as fluxes in the Hanging-Rock district. Of the Buff or Shawnee limestone, Orton gives seven analyses by Howard, as follows: No. 6, Ogden (now Helen) furnace; No. 7, XX furnace, Shawnee; Nos. 8 and 9, Fannie furnaces, Shawnee; No. 10, W. W. Poston's, Nelson-

ville; No. 11, W. B. Brooks's, Nelsonville; No. 12, G. W. Gill's, Meeker's Run, in York.

*II. Analyses of Shawnee Limestone.*

| | No. 6. | No. 7. | No. 8. | No. 9. | No. 10. | No. 11. | No. 12. |
|---|---|---|---|---|---|---|---|
| Carbonate of lime, . . . | 92.62 | 81.65 | 87.66 | 78.15 | 85.32 | 72.08 | 76.00 |
| Carbonate of magnesia, . . | .96 | 1.96 | 1.16 | 2.07 | trace. | trace. | – |
| Iron oxyd and alumina, . . | 3.63 | 4.99 | 7.27 | 6.81 | 2.99 | 3.91 | 3.45 |
| Silicious matter, . . . | 2.91 | 10.42 | 3.57 | 11.81 | 10.12 | 22.23 | 19.85 |
| Total, . . . . . | 100.12 | 99.57 | 100.24 | 99.45 | 99.29 | 69.22 | 99.60 |

§ 192. Of the Cambridge limestone I find one analysis by Howard, said to be from the stock-pile of the Ogden furnace, and probably quarried in the vicinity. To this, given below as No. 13, are added two by Gregory of the Cambridge limestone from Moxahala; No. 14, being from the bottom, and No. 15 from the top layer.

*III. Analyses of Cambridge Limestone.*

| | No. 13. | No. 14. | No. 15. |
|---|---|---|---|
| Carbonate of lime, . . . . . | 90.30 | 86.86 | 80.76 |
| Carbonate of magnesia, . . . . . | .92 | .68 | .65 |
| Iron oxyd and alumina, . . . . . | 4.42 | – | 9.84 |
| Silicious matter, . . . . . | 3.67 | 7.37 | 8.75 |
| Total, . . . . . | 99.31 | – | – |

The iron oxyd in No. 14 was equal to 1·58 per cent., and that in No. 15 to 4·79 per cent. of metallic iron. The analysis of a third specimen from this locality, also from the bottom layer, gave to Gregory, besides 65·06 of carbonate of lime, and 10·57 of silicious matter, not less than 3·40 of oxyd of manganese, and 20·45 of carbonate of iron, equal to

about 10·0 per cent. of metallic iron. These analyses show the progressive admixture by which the limestones, as already explained, pass in some localities into iron ores.

§ 193. Of the Ames limestone we have two analyses by Howard. No. 16 is said to be from a stock-pile at the Ogden furnace, which was got from the outcrop of this limestone noticed in § 128 as seen in section 33 of Trimble. No. 17 is from the land of L. D. Linscott in section 30 of Dover.

To these we append three analyses of a limestone which is quarried near the city of Columbus. This limestone belongs to what is known as the Corniferous formation, and occupies a position much below the coal, — at the base of the Devonian series. The Columbus limestone, from its purity and its accessibility, has been used to a considerable extent as a flux for the iron-furnaces of the Hocking Valley. Of the following analyses, Nos. 18 and 19 are by Howard, the samples, according to Orton, having been taken from Smith and Price's quarries, two miles west of the city. The first analysis shows the best grade of the limestone. The second is from a lower level in the same quarry. No. 20 is by Dickinson, and represents the average of a quantity of this limestone brought to the Lee furnace for use as a flux.

*IV. Analyses of Ames and Columbus Limestones.*

| | No. 16. | No. 17. | No. 18. | No. 19. | No 20. |
|---|---|---|---|---|---|
| Carbonate of lime, . . . . | 94.18 | 91.71 | 93.28 | 81.44 | 90.67 |
| Carbonate of magnesia, . . . | 1.02 | .72 | 2.69 | 16.00 | 6.50 |
| Iron oxyd and alumina, . . . | 2.44 | 2.67 | 2.10 | 1.08 | .72 |
| Silicious matter, . . . . . | 2.23 | 4.57 | 1.41 | 1.94 | 1.40 |
| Total, . . . . . | 97.87 | 99.67 | 99.48 | 100.46 | 99.29 |

The "Silicious matter," which appears in the analyses of the above limestones, consists, as in the iron ores (§ 182), of silica, with more or less alumina.

## BLAST-FURNACES AND IRON-SMELTING.

§ 194. A district extending from the Ohio River to the south-western part of the Hocking Valley coal-field, has for nearly half a century been the seat of an important iron-manufacture. The commencement of this dates from the erection in 1827 of a blast-furnace near the village of Hanging Rock in Lawrence County, on the Ohio, from which point the industry spread northwards, including parts of Lawrence, Scioto, Gallia, Jackson and Vinton counties; the whole of which area has come to be known as the Hanging-Rock district. In 1869 there were in this region forty-five furnace-stacks, mostly of small size, using charcoal as fuel, besides five using mineral coal or coke, the aggregate production of pig iron from these in that year amounting to 106,000 tons, of which over 90,000 tons were probably charcoal-made iron. The excellence of the Hanging-Rock iron is well known, and it has always commanded a high price in the markets.

§ 195. In September, 1878, according to the Directory published by the American Iron and Steel Association, there were in the Hanging-Rock district (which was made to include a charcoal-furnace in Brown, one in Starr, and one at Logan) thirty-one furnace-stacks for charcoal-iron, with an aggregate annual capacity of 127,000 tons, varying from 3,000 to 5,000 each. Besides these were seventeen stacks employing mineral fuel, chiefly raw coal, with the exception of the Belmont furnace, consuming Connellsville coke, and a small furnace at Vinton station using native coke. These furnaces varied in size from small stacks of 4,000 tons annual capacity, to large ones like the Belmont and Etna, sixty-six and eighty-six feet in height, respectively, with capacities of 15,000 and 20,000 tons.

§ 196. Of the above charcoal-furnaces the greater number were out of blast in 1878, as is shown by the fact that

while their annual capacity of production was 127,000 tons, the total production of charcoal-iron in Ohio, which in 1873 attained 100,498 tons, had fallen in 1878 to 33,513 tons, and was only 43,445 tons in 1879. The whole of this was from the Hanging-Rock region, which yielded besides, 43,097 tons of iron smelted with mineral fuel, a total of 86,532 tons, showing a considerable falling-off from 1869. Meanwhile the total iron-production of Ohio, instead of falling off, augmented from 406,029 tons in 1873 to 447,751 tons in 1879. The growing scarcity of charcoal has caused it to be replaced in great part by mineral fuel, dry-burning coals of excellent quality being found near the base of the coal-measures at some points in the Hanging-Rock district.

§ 197. The blast-furnaces of this region have been from the first supplied with native ore, and, with few exceptions, with what is known as the Limestone ore or Baird ore. We have cited (§ 81) Prof. Orton's assertion in 1878, that more than sixty furnaces in southern Ohio make this ore their chief dependence. Besides the thirty-one charcoal-furnaces and seventeen mineral-coal and coke furnaces of the Hanging-Rock region, there could at that time be counted four new furnaces then in blast in the Hocking Valley, which were using this ore; namely, the Baird, Gore, Bessie and Winona, besides the Franklin furnace of Columbus, not then in blast. But of the charcoal-furnaces named, the greater number were not then in activity, as appears from their small production, so that the whole number of furnaces then smelting this ore could hardly exceed thirty.

§ 198. Soon after the opening of the Hocking-Valley coal-field by railroads, the value of the coal from some parts of the Great Vein as a fuel for iron-smelting was discovered. It was used to some extent in a furnace at Cleveland, Ohio, as a substitute for the block coal of the Mahoning Valley, and in the years 1870–73, three blast-furnaces were erected,

two at Columbus and one at Zanesville, for the purpose of smelting a mixture of the rich ores of Lake Superior with the native ores found along the borders of the Hocking-Valley coal-field; the fuel used being the raw coal from the Great Vein, mined at New Straitsville. A fourth furnace for the same object was built at Newark, Ohio, in 1874–5.

§ 199. Up to 1874, however, no blast-furnaces for the use of this coal had been erected within the area of the coal-field, and there was a general opinion that the coal of the Great Vein south of Straitsville was unfit for iron-smelting. In a report on the Hocking Valley coal-field published in May, 1874, however, the present writer attempted to combat this notion, and pointed out that the coals of Nelsonville and Haydenville, from their chemical and physical characters, were in no wise inferior for the purpose named to those mined in the vicinity of Straitsville, and added, "It may be confidently predicted that they will be found equal to these in the blast-furnace." At the same time it was said that "the dry-burning character of the coal of the Great Vein mined in Starr, and at Lick Run, in the western part of York, is very marked."

§ 200. At this date, also, no attempt had been made to develop the iron-ores above the Gray limestone, although Andrews, Read and Weethee had, by multiplied observations, shown the existence of numerous ore-horizons between this limestone and the Pittsburgh coal-seam, and had insisted on their economic importance. Their observations, with the addition of many of my own, were brought together in the report just cited, where it was said: "It will be seen from the statements which have been given that the quantity of iron-ore in this region is very great, and that the supply within the limits of the Hocking-Valley coal-field, and along its borders, will probably last as long as the coal itself, since each ton of these ores requires about a ton of coal to convert

it into pig iron." It was farther declared that should the fitness of the mineral coal of this region for iron-smelting be established, "the future of the iron-industry of southern Ohio is assured for generations to come, and the cost of producing iron will, from the abundant and cheap supply of both ores and fuel, be less there than in any other equally accessible part of the country." (*Loc. cit.* pp. 58, 60.)

§ 201. In 1874, the late Mr. S. Baird, of Columbus, commenced the erection of a blast-furnace in the south-east part of Monday Creek township, near the outcrop of the Great Vein of coal, which was to be used for smelting a vein of ore found a little below it. This ore-deposit, which he was the first to develop in the Hocking-Valley field, received the name of the Baird ore, and was subsequently declared by Prof. Orton to be the equivalent of the well-known Limestone ore of the Hanging-Rock district. The structure, which is known as the Baird furnace, had a height of 44 feet, with a diameter of $11\frac{8}{12}$ feet at the boshes, and went into blast in October, 1875. It was the first mineral-coal furnace in the Hocking-Valley field, and has continued in successful operation.

A second furnace in the same vicinity was soon after erected by the Thomas Iron Co., near Gore station, about three miles west of New Straitsville, and was put in blast in December, 1876. It is 47 feet high, with $12\frac{6}{12}$ feet bosh.

§ 202. Meanwhile the rich deposit of ore known as the Iron Point black-band had been discovered near Shawnee, and in 1876 the blast-furnace which had been completed at Newark in 1875, was removed and set up at Shawnee, where it went into blast in September, 1876. A companion to this was soon built, and put in blast in October, 1877. These twin furnaces, known as Fannie No. 1 and No. 2, are the property of the Licking Iron Co., and as since remodelled, are each 50 feet high, with boshes of 12 and 13 feet. Two

additional blast-furnaces were now erected at Shawnee; the XX, of the dimensions 50 × 14, which was blown in in January, 1877, and the Mollie or Vilas furnace, 50 × 14½, in November of the same year. All of these depend chiefly on the black-band of the vicinity. We have, however, already mentioned some other sources of ore utilized by the Licking Iron Co. (§ 186.)

§ 203. In January, 1878, a blast-furnace 50 × 14 feet, called the Bessie, and situated about a mile west of New Straitsville was put in operation, and in February of the same year another, 50 × 12½ feet, called the Winona, near Webb station in Gore, Still another, the Crafts furnace, 57 × 15 feet, removed from Newport, Ky., and rebuilt in the north-east part of the township of Green, at Greendale station, was put in blast in November, 1879. The five furnaces west of Straitsville, namely, the Baird, the Gore, the Bessie, the Winona and the Crafts, use chiefly the Baird ore, with some admixture of ores from Lake Superior.

In January 1878, also, a new furnace was put in blast in the north-west part of the field, at Moxahala, for the smelting of the abundant ores of the vicinity. This, which is called the Moxahala furnace, is 55½ × 15 feet.

§ 204. Meanwhile attention was drawn to the coals of the more southern part of the field, and in 1877 the Akron Iron Co. acquired a tract of land a little east of Nelsonville, — near a town-site which, in anticipation of its future importance as an iron-manufacturing centre, had been named Bessemer, — and rebuilt there a blast-furnace which had been erected in 1872 at Akron, Ohio. The president of the company, Mr. Buchtel, opened what has since been called the Buchtel ore, and in November, 1877, the furnace was put in blast, using this ore with the coal of the Great Vein below it. The dimensions of this, which is called the Akron furnace, were at first 50 × 16 feet, but it has been considerably enlarged.

§ 205. In the same year, 1877, another furnace was erected about two miles to the north-east of the Akron, in the valley of Snow Fork, at a site which received the name of Orbiston, the furnace itself being called the Ogden, a name which, since its acquisition by the Hocking Iron Co. in 1880, has been changed to that of Helen. This furnace, the dimensions of which were 50 × 15 feet, went into blast in December, 1877.

The furnace already mentioned as having been put up at Columbus in 1870, was in 1878 rebuilt on Monday Creek, about two miles west of the one just named, and took the name of the Monday Creek furnace. Its dimensions were 53 × 14 feet, and it went into blast in March, 1878. This also was purchased by the Hocking Iron Co. in 1880, and has since been called the Lee furnace.

§ 206. We have thus seen that from 1874 to 1879 thirteen blast-furnaces consuming the native ores and the raw coal of the Great Vein were erected in the Hocking-Valley field. The height of these furnaces was gradually increased from 44 to 57 feet, experience having shown that the coal is able to sustain a greater burden than was at first supposed. Encouraged by these results, the Franklin furnace of Columbus was, in 1879, remodelled, and is now 65 × 17 feet. The Akron furnace also, within the year 1880, has been enlarged to the same dimensions, the daily production of iron in each case being now from forty to fifty tons.

§ 207. A new organization, called the Buchtel Co., has during the year 1880 acquired a tract of land between Monday Creek and Sunday Creek, a little to the south-east of Bessemer, and is now erecting, opposite Floodwood station, two furnaces, which will be each 65 × 17 feet, with a capacity of 9,000 cubic feet; the furnaces having eight five-inch *tuyères* and the Lurmann closed front. The blowing-engines for each furnace are calculated to deliver 20,000 cubic feet of air per

minute, at a pressure of ten pounds. For heating the blast there are to be provided one set of four cast-iron Thomas stoves, having 8,000 square feet of heating-surface, and one set of three Cowper-Siemens stoves, with 100,000 square feet of surface. It is proposed to substitute native coke, either wholly or in part, for the raw coal of the Great Vein. According to Mr. John B. Pearse, the consulting engineer of the Buchtel Co., it is expected that the daily capacity of these furnaces will not be less than 100 tons each. They will probably be completed during the summer of 1881.

§ 208. The early history of many of the Hocking-Valley furnaces was one of frequent failure and disappointment. Started during a period of great commercial depression, when the price of iron was very low, and undertaken in many cases by persons who had little or no experience in the business of iron-manufacture, and often insufficient capital, financial troubles and embarrassments forced several of the furnaces to suspend operations after a short time. To this, however, there were not wanting many exceptions. The Baird, Gore, Crafts, Vilas, and Akron furnaces, at least, have had from the first a successful career, and with the general revival of the iron-trade which began in 1879, prosperity has returned to the region. The iron-production of the Hocking-Valley furnaces in 1878 was 70,500 tons, but fell in 1879 to 51,908 tons. The year 1880 has, however, seen the whole of the furnaces in operation, though in some cases for a part of the time only, repairs and improvements in the case of the Baird, the Akron, the Helen and the Lee, having kept these furnaces out of blast for several months. General Samuel Thomas, president of the Thomas Iron Co., and of the Columbus Rolling Mills, estimates the total production of the thirteen furnaces for 1880 to be equal, in round numbers, to 91,000 net tons. To this should be added that of the Zanesville furnace, and of the Franklin furnace, of Columbus,

which, though outside of the limits of the coal-field, draw from it their supplies of coal and ore. That of Zanesville gets its coal from Shawnee, while the Franklin furnace is supplied from the mines of the Akron Co., at Buchtel station, near Bessemer. The production of these two furnaces for 1880 is estimated by General Thomas at 10,000 and 15,000 tons respectively, making a total of 116,000 net or 102,200 gross tons. It may be added that the Logan furnace is now in activity, and made in 1880 about 2,000 tons of charcoal-iron.

§ 209. As already mentioned, the four furnaces at Shawnee employ native ores only, while those of the western group, namely, the Baird, Bessie, Gore, Winona and Crafts, use with these an admixture of from one-fifth to one-third of Lake Superior red hematite or specular ore. The Akron furnace has also smelted a portion of Lake Superior ore with that from the Buchtel seam, or with a mixture of this last with the Baird ore. The Lee and Helen have hitherto smelted the Buchtel ore with little or no admixture, but the Helen, which has been out of blast for repairs, is to commence early in 1881, the use of the Helen black-band ore, of which about 4,000 tons were mined in the six months from its discovery in May last.

§ 210. A preliminary roasting or calcination of ores such as the carbonates and limonites, is necessary to their successful smelting. The plan of roasting hitherto adopted in this region has been the primitive one of piling them in large rectangular heaps, with a layer of fire-wood at the base, and an admixture of small coal or slack throughout the pile. The wood being kindled, a slow combustion, lasting several weeks, effects the calcination of the ore. To this plan there are, however, many objections: it is slow, and at the same time irregular in its operation, some portions of the ore being often but partially roasted, while others, from exces-

sive heat, become half fused, and run together, so as to require breaking up.

The practice in many parts of Europe is to roast the ore in kilns, of which there are various models. That of Gjers, used in the Cleveland district in England, is constructed of fire-brick, cased with wrought-iron plates, and is like the body of a wide, low, blast-furnace in shape. In kilns of this kind, thirty-four feet high, a charge of ore is roasted in three days' time, with a consumption of four tons of coal-slack to 100 tons of ore. Some kilns are made so as to be continuous in their operation. Kiln-roasting presents great advantages alike from the regularity and quickness of the operation, and the economy of fuel. It is the intention of the Buchtel Co. to adopt this method at their new blast-furnaces near Floodwood.

§ 211. The consumption of coal in iron-smelting in this region has not yet received the attention which it deserves, and but little regard seems to have been had to economy in fuel. The average record of the Akron and Fannie furnaces in 1879 showed a consumption of considerably over three net tons of 2,000 pounds to the gross ton of pig iron, but better practice will doubtless reduce considerably this amount, which must be regarded as excessive. From the books of the Fannie furnaces for 1879, it appears that for the production of 9,030 gross tons of iron there had mined 32,994 tons of coal, which, however, included coal for various other local uses, being at the rate of $3\frac{65}{100}$ tons to the ton. The record of some single weeks' running, as calculated from the charges, as taken from the furnace-book at one of the Fannie furnaces, showed a much smaller consumption of fuel. In one week, for example, $165\frac{1}{2}$ tons of pig iron were made from $288\frac{1}{2}$ tons of calcined Iron Point ore, with 434 tons of coal, being at the rate of $2\frac{63}{100}$ tons of coal to the ton of iron. With judicious working the consumption of fuel ought to be kept within these limits. It has been found most advanta-

geous in practice to use only the lower half of the coal of the Great Vein.

§ 212. The metal produced in the furnaces of this region is chiefly foundry iron, with, however, a considerable proportion of mill iron. There are but few analyses of these irons known to me. Of the five given below, No. 1 is by Gregory, of Fannie foundry iron, and is what might be expected from the ores. The remaining four were given me by the president of the Licking Iron Co., to whom the name of the analyst was unknown. Their small amount of phosphorus is surprising, and creates a suspicion of errors in determination, while the proportion of silicon, especially in the last two, is very unusually large. They are preserved rather as curiosities than as indicating the composition of the irons of the region, and indicate either errors in analysis or very exceptional conditions in smelting. Nos. 2 and 3 are said to have been Baird foundry and mill irons; No. 4, a white iron, from the Gore furnace; and No. 5, also from the Baird furnace.

| | No. 1. | No. 2. | No. 3. | No. 4. | No. 5. |
|---|---|---|---|---|---|
| Iron, by difference, . . | 91.45 | - | - | - | - |
| Carbon, combined, . . | .24 | .66 | 1.37 | .63 | 1 325 |
| Carbon, graphitic, . . . | 2.31 | 3.41 | 3.14 | 2.04 | 3.195 |
| Silicon, . . . . . | 3.89 | 4.37 | 3.91 | 8.24 | 9.686 |
| Phosphorus, . . . . | .79 | .017 | .011 | .013 | .003 |
| Sulphur, . . . . . | .03 | .02 | .014 | .007 | .036 |
| Manganese, . . . . | .65 | - | - | - | - |

§ 213. The native ores, as we have seen from their analyses, contain a considerable quantity of phosphorus, which should be found in the iron made from them. Two analyses of foundry-pig by Drown, in 1874, the one of charcoal-iron from the Logan furnace, and the other from the

Globe furnace at Jackson, smelted with raw coal, gave respectively 0·44 and 0·84 of phosphorus; while four analyses by Howard of Columbus, cited by Orton, of different grades of pig-iron made at the Star furnace in Jackson County in the Hanging-Rock district, exclusively of native ores with raw coal, gave 0·40 to 0·63 of phosphorus.

§ 214. What is known as mill-cinder is to some extent used in blast-furnaces as a substitute for natural ores. This plan has been adopted to some extent throughout Ohio, and has lately—according to Dr. J. P. Kimball, to whose recent paper on the utilization of mill-cinder, read in August, 1880, before the American Institute of Mining Engineers, I am indebted for many important suggestions and facts—become general in western Pennsylvania. Mill-cinder is especially used in the furnaces attached to rolling-mills in and about Pittsburgh, where its use was stimulated by the scarcity of ores and the high prices prevailing at the commencement of 1880.

The name of mill-cinder is applied to two products, the one the tap-cinder from the puddling-furnaces, the other the cinder from the re-heating furnaces. These agree in composition in consisting chiefly of a silicate of protoxyd of iron, and in yielding about 50·0 per cent. of metal. The cinder, especially the tap-cinder, always contains a large proportion of the phosphorus of the pig-iron from which it is derived, this element being, as is well known, in great part eliminated in the process of puddling, and concentrated in the cinder, so that when made from a highly phosphorized pig this holds a considerable amount of phosphorus. The results of a series of analyses of mill-cinder made by Prof. Wormley for the Geological Survey of Ohio (Vol. III., pages 879, 880), are subjoined. No. 1, tap-cinder from the Columbus rolling-mill; No. 2, tap-cinder from the Marietta rolling-mill; No. 3, tap-cinder from the Ironton rolling-mill; Nos. 4, 5 and 6 are cinders from the re-heating furnaces of the same

rolling-mills, in the order named, and thus corresponding to the tap-cinders Nos. 1, 2 and 3.

*Analyses of Mill-Cinder.*

| | No. 1. | No. 2 | No. 3. | No. 4. | No. 5. | No. 6. |
|---|---|---|---|---|---|---|
| Silica, . . . . . | 21.00 | 21.58 | 30.00 | 21.20 | 24.51 | 29.60 |
| Iron oxyd, . . . . . | 67.69 | 63.38 | 65.04 | 69.44 | 63.30 | 64.67 |
| Metallic iron, . . . | – | 7.12 | – | – | 6.80 | 2.35 |
| Manganese oxyd, . . | .50 | Traces. | 1.60 | .15 | Traces. | Traces. |
| Alumina, . . . . . | 2.80 | .30 | 1.20 | .40 | .35 | 2.40 |
| Lime, . . . . . | 4.07 | 2.10 | .20 | 2.19 | 2.50 | .44 |
| Magnesia, . . . . . | .37 | 1.50 | Traces. | .90 | 1.40 | Traces. |
| Total metallic iron, . . | 52.81 | 51.42 | 50.59 | 54.00 | 51.10 | 52.65 |
| Phosphorus, . . . . | 1.28 | 1.40 | .54 | .39 | .36 | .23 |

The alumina, lime, and magnesia, and a portion of the silica of these cinders, are derived from slag adhering to the pig-iron, or in part, perhaps, from the fettling. These same sources, and perhaps the furnace-bottom, furnish a farther portion of the silica, the rest of which is derived from the oxydation of silicon contained in the pig. The metallic iron in Nos. 2, 5, and 6 is due to grains of iron included in the cinder.

§ 215. Mill-cinder is rarely used alone in the blast-furnace, though according to Kimball a furnace at Covington, Kentucky, has for several months made foundry-pig from cinder alone. The effect of a considerable proportion of phosphorus in pig-iron is to render the metal very fluid and well fitted for the founder's use; but an excess of this element renders the metal cold-short, and fit only for castings in which this quality is not objectionable. The admixture of a portion of mill-cinder with the rich ores of Lake Superior, which are almost free from phosphorus, and yield

a red-short iron, is advantageous, as correcting this tendency to red-shortness and giving a neutral iron. For a similar object, native phosphorized ores, like those of the Hocking Valley, are smelted with the Lake Superior ores. It will, however, readily be seen that the addition of highly phosphorized mill-cinder to ores which already contain a considerable proportion of this element can only tend to make the phosphorus in the resulting metal excessive. This will especially be the case when the cinder from puddling such iron is used a second time in the blast-furnace, for the phosphorus becomes thereby accumulated in the pig metal. If, therefore, it is desirable to make any admixture with native ores like those of the Hocking Valley, Lake Superior or other non-phosphorized ores should be preferred to mill-cinder, even at a greater cost. It is only where a special dephosphorizing process, such as will be mentioned below (§ 224), can be applied to the product that ordinary mill-cinder can be smelted with advantage with phosphorized ores.

§ 216. The object of fluxes in iron-smelting is to remove in a fusible form the impurities of the furnace-charge with the least expenditure of fuel and other materials. When rich and pure ores are smelted with charcoal the chief aim is so to adjust the charge that the mixture may form the most fusible slag. When, however, the fuel is mineral coal or coke, it is necessary to produce a slag capable of absorbing the sulphur which these fuels always contain, and which would otherwise pass into the metal. The flux most commonly used for this purpose is lime, and to this end a larger amount is used than would be necessary to form the most fusible slag. The composition of the earthy matters which form the ash of the fuel must also be taken into account in this connection.

§ 217. Blast-furnace slags, except in some rare cases which we need not here consider, are compounds of silica

with alumina and lime, the latter being often replaced in part by magnesia, and sometimes by oxyd of manganese. Besides these, they contain a variable proportion of oxyd of iron, which, if the furnace is in good working order, is seldom above 2·0, and sometimes falls to 0·5 per cent. The sulphur which slags contain is generally represented as united with the metallic base of lime, forming a sulphid of calcium; but manganese, and, it is believed, alumina, share with lime the power of thus fixing sulphur.

These double silicates are conveniently referred to three types, according to the proportions between the oxygen of the silica and that of the alumina and other bases united. Those in which the oxygen ratio between the silica and the bases is 100 : 100 are called unisilicates, those in which it is 100 : 50 being bisilicates, and those in which it is 100 : 33⅓ tersilicates.

With some exceptions, the composition of blast-furnace slags varies between unisilicates and bisilicates. The most fusible slags are bisilicates, and the most fusible compound of silica, alumina and lime, according to Bodemann, is such a silicate containing in 100 parts silica 56, alumina 14, lime 30. The proportion of alumina to silica varies very much in different slags, but generally exceeds that of 25 per cent. found in the above formula. We select six analyses which may be regarded as representative of slags from English and Belgian blast-furnaces in which the argillaceous carbonate ores of the coal-measures are smelted with coke. Of these slags, the first two are essentially unisilicates, and the others approach more or less to bisilicates in composition, as will be seen by the oxygen of their united bases, which for 100 parts of oxygen in the silica amounts respectively to 99, 101, 95, 81, 69, and 92. In these six slags we find the alumina equalling 39·3, 37·0, 34·4, 31·0, 25·3, and 47·0 per cent. of the silica present. The proportion of alumina in some slags is still greater than in the last,

as may be seen in the very basic slags obtained in smelting the argillaceous carbonate ores of the Cleveland district in England. Four analyses of these slags from Clarence, Middlesborough (one of which is given in the table below, show amounts of alumina equal respectively to 60·8, 72·5, 80·0, and 88·0 per cent. of the silica present. The difficulties in smelting these ores, which require very high temperatures, and do not readily yield vitreous slags, are conceived by Lowthian Bell to be due to the relatively large proportions of alumina and the deficiency of silica — defects not to be corrected by the addition of lime. The analyses of the six slags just referred to may be found under the title IRON in Watts's Dictionary of Chemistry, Vol. III., pages 360–361.

§ 218. The only analyses of slags from the Hocking Valley region known to me are two by Dickinson, chemist to the Hocking Iron Co., of slags from the Lee furnace in the autumn of 1880, when smelting the Buchtel ore. Of these, No. 1 in the table is said to have been made while using as flux Columbus limestone (see analysis No. 20, page 109); while No. 2 was produced when a native limestone (probably the Buff or Shawnee) was employed as a flux. They are both highly basic aluminous slags, which approach in composition No. 3 of the same table, one of those slags already noticed as produced in smelting the Cleveland ore at Middlesborough in England. This analysis has been recalculated to make it comparable with the two preceding, by separating from the total amount of lime, as given, that which exists as calcium combined with sulphur, thus leaving of lime 36·95 per cent. The oxygen contained in the several ingredients is given in the column adjoining the analysis, while the "Oxygen ratio" for each analysis shows the amount of oxygen in the united bases for 100 parts of oxygen contained in the silica, making these slags in each case far more basic than unisilicates. The amount of alumina for 100 parts

of silica is given as "Alumina : Silica." The minute portion of phosphoric acid has been disregarded in calculating the oxygen ratios.

*Analyses of Blast-Furnace Slags.*

| | No. 1. | Oxygen. | No. 2. | Oxygen. | No. 3. | Oxygen. |
|---|---|---|---|---|---|---|
| Silica, . . . . . | 26.80 | 14.29 | 25.73 | 13.72 | 27.80 | 14.82 |
| Alumina, . . . . . | 14 25 | 6.64 | 14.55 | 6.78 | 22.28 | 10.38 |
| Lime, . . . . . | 47.61 | 13.60 | 49.72 | 14.00 | 36.95 | 10.55 |
| Magnesia, . . . . . | 2.82 | 1.13 | 1.84 | .74 | 7.21 | 2.85 |
| Protoxyd of iron, . . | 1.76 | .39 | .90 | .20 | .61 | .13 |
| Protoxyd of manganese, . | .33 | .07 | .28 | .06 | - | - |
| Phosphoric acid, . . | .18 | - | .087 | - | - | - |
| Calcium, . . . . . | 2.46 | - | 2.60 | - | 2.50 | - |
| Sulphur, . . . . . | 1.97 | - | 2 08 | - | 2.00 | - |
| Oxygen ratio, . . . | 1 52 | - | 1.56 | - | 1.61 | - |
| Alumina : Silica, . . . | 53.1 | - | 57.7 | - | 80.0 | - |

§ 219. A comparison of the analyses, Nos. 1 and 2, with those of the Buchtel ore, on page 98, shows that the slag is much more aluminous than the ore itself, which is due to the large proportion of alumina in the ashes of the fuel. The analysis of Connellsville coke, on page 82, shows that 100 parts of it yield over eleven parts of ash containing 47·00 per cent. of silica and as much alumina, and the examinations by Wormley of the ash of Ohio coals prove some of these to be almost equally aluminous, while others contain a somewhat larger proportion of silica. Thus, a coal from Jackson County yielded 2·36 per cent. of an ash which contained silica 44·60, and alumina 41·10; while a portion from the Great Vein, mined at New Straitsville, gave 5·14 per cent. of an ash yielding silica 58·75, and alumina 35·20.

The argillaceous shales which are associated with coal-beds, and are similar in composition to the earthy matters which form the ashes of coal, are, in some cases, used as a flux to supply alumina in the smelting of silicious ores.

§ 220. In the slags of the Lee furnace, as in those of Middlesboro', already cited, there is an excess of alumina, and a deficiency of silica, defects which are readily corrected by adding to the charge, mill-cinder or, better, for reasons already given, the more silicious ores of Lake Superior. In a paper read in July, 1880, to the Amer. Inst. of Mining Engineers, Dr. J. P. Kimball says: "Millions of tons of second and third grade specular ores, already mined and stocked on the dumps of the Lake Superior mines, as refuse, can be afforded cheap for shipment." Their chief impurity is a silicious, jaspery admixture, and they will contain, according to him, 50·0 per cent. and over of metallic iron. These silicious ores can best be utilized by mixing them with the argillaceous ores of the coal-measures; or, as suggested by Kimball, with ores such as the highly aluminous magnetites first described by him, which are found in large quantities in Westchester County, New York, and possess, in a greater degree, the properties of the hydrated aluminous ores of Belfast, Ireland, which are now imported to some extent to the United States.

§ 221. The amount of lime, equal to nearly one-half their weight, in the slags from the Lee furnace, is excessive. Too large a proportion of lime causes a difficultly fusible slag, augments the consumption of fuel, and reduces the productive capacity of the furnaces. It is greatly to be desired that we had, for comparative study, analyses of the slags from other furnaces using the Buchtel ore, as well as from furnaces smelting the Shawnee ore, and the Baird ore, whether alone or in admixture with the ores of Lake Superior.

The considerable amount of oxyd of manganese contained

in the black-band ores, and especially in that from the Helen furnace, will prove of itself a most valuable flux.

§ 222. It is only by a careful chemical study, alike of the ores, the fluxes, the fuel, the slags, and the metal, that we can arrive at the best conditions of smelting, and by reducing the consumption of fuel, and augmenting the output of our furnaces, bring down the cost of producing iron. American skill and science have already effected such results in many other departments of industry as enable us to compete successfully in the markets of the world. In the production of Bessemer steel, and its subsequent working, we are acknowledged masters, but as regards the smelting of iron, comparatively little progress has been made. In this, as in all other industries, it is now indispensable that our manufacturers should be trained in the scientific principles which form its basis. Crude, empirical modes of working must be abandoned, and scientific practice, based on careful chemical analyses, and guided by the highest metallurgical skill in the use of materials, the construction of furnaces, and the supply and temperature of blast, must take its place, as it has already done to a great extent in the chief European centres of iron-production. In this way, and in this way only, shall we be enabled rightly to use our great resources in iron-ores and fuel, and by reducing the cost of making iron, be enabled to become exporters of iron and steel.

§ 223. Mention may here be made of a recent application of chemical science to the successful solution of one of the most important problems in the metallurgy of iron; namely, its dephosphorization in the pneumatic or so-called Bessemer process, which up to the present time could only be applied to pig-irons comparatively free from phosphorus. It is generally known that the conversion of crude iron into Bessemer metal is effected in a few minutes with masses of several tons, by blowing air into the iron while held in a molten condition in great iron convertors, which have an infusible sili-

cious lining to resist the intense heat generated in the operation. In this process, the chief impurities of the iron, such as carbon and silicon, are oxydized and separated in the forms of gas and slag. It is, however, found impossible to remove phosphorus in this way, for although, as we have seen, it is readily oxydized in the puddling-furnace, and passes into the basic mill-cinder, the silica which forms the lining of the ordinary Bessemer convertor, at the high temperature prevailing, at once liberates the phosphorus again, and allows it to re-unite with the iron. As a result of this, the whole of the phosphorus of the pig-iron is found in the Bessemer steel. Inasmuch as an amount of this element which would be unobjectionable in the best cast or wrought iron, greatly impairs the value of steel, the application of this method has hitherto been restricted to irons made from ores comparatively free from phosphorus.

§ 224. The solution of the problem of utilizing for the production of Bessemer steel the iron made from ordinary phosphorized ores, is found to be in effecting its conversion out of contact with free silica. This discovery has been perfected through the combined labors of several chemists, and is embodied in what is generally known as the Thomas-Gilchrist or basic process, which consists in the use of convertors having a non-silicious lining, composed chiefly of lime, and moreover in adding to the molten metal, during the process of conversion, small quantities of lime and iron-oxyd. The amount of phosphorus in pig-iron intended for the production of steel in the ordinary convertors is generally from 0·03 to 0·06, and should never exceed 0·10 per cent. The trials with the basic lining in England have been made on the Cleveland pig-iron, remarkable for holding not less than from 1·20 to 1·30 per cent. of phosphorus, and it has been found possible, by the use of the Thomas-Gilchrist process, to dephosphorize this so completely in the Bessemer convertor that the resulting steel is as free from phos-

phorus as that made from the best pig-irons; the conversion by this process being effected with but little additional cost. Experiments on a large scale have been going on since early in 1879, at the steel-works of Messrs. Bolckow, Vaughan & Co., at Middlesboro', in England, and it is announced in 1880 that the basic process has there been brought to a technical and commercial success. The same process is already in use in several steel-works on the continent of Europe, and among others at Creusot in France, where it has also been successfully applied on a large scale to the dephosphorization of pig-iron in the production of steel in the open hearth, by what is known as the Siemens-Martin method, a lining of lime-bricks being substituted for the silicious lining ordinarily used in the Siemens furnace.* Steel has been successfully made by the basic process from mill-cinder pig-iron containing 2·5 per cent. of phosphorus.

§ 225. The practical result of the success of this method will be, by enabling the iron from the cheaper and more common ores to be used for the manufacture of Bessemer steel, to do away with the monopoly which certain ores, like those of the Barrow district in England, and those of Lake Superior and the Missouri Iron-Mountain region, have hitherto enjoyed for the manufacture of Bessemer steel. Among the vast deposits of iron-ore known to the east of the Alleghanies, there are found, alike in Pennsylvania, New Jersey and New York, certain mines which yield ores fit for this purpose, technically called Bessemer ores; but they are wholly inadequate to supply the demands of our extensive manufacture of Bessemer steel. Great Britain has for many years been largely dependent for her supply of such ores on Spain and Algeria, and the eastern United States have found it more advantageous to import these rich ores than to get them from Missouri and northern Michigan.

* *La Métallurgie*, of April 14, cited in *The Engineering and Mining Journal* of July 10, 1880.

§ 226. This new commerce was insignificant in amount previous to the revival of business in 1879. In that year, however, our importation of foreign ore reached 284,141 tons, while for 1880 it is estimated in round numbers by Mr. Swank at 400,000 tons. For the fifteen months ending March 31, 1880, there were imported into the United States 377,682 gross tons of iron-ore, valued at $957,268, or an average invoice-value of $2.53 per ton. Of this I find a very small portion, amounting to 20,261 tons, was entered at ports on the great lakes, and may be set down as Canadian ore. The remainder, or more than 375,000 tons, was entered chiefly at the ports of New York, Philadelphia and Baltimore, and was for the greater part Spanish and African ore, though including a small portion of the aluminous ore from Belfast, Ireland. These high-grade ores, which pay a duty of 20 per cent. *ad valorem*, are brought out at low rates of freight, and have been a great aid to our makers of Bessemer and open-hearth steels.

§ 227. The dephosphorizing process, which will enable us to utilize for the manufacture of Bessemer steel the abundant magnetites of New York, New Jersey and the Blue Ridge; the limonites of the great Appalachian Valley, and the various Silurian and Devonian ores of its western borders, would make us independent of foreign ores, and would equalize the present differences in price between these, for the most part phosphorized, ores and the purer ores of Lake Superior, which have the great merit of yielding an iron so free from phosphorus that it can be readily used in the ordinary Bessemer convertor for the production of steel. The region south of Lake Superior now furnishes a great amount of ore, and its capacity for production is enormous. The shipments of ore therefrom in 1878, were 1,125,083 tons, and for 1879, 1,414,182 tons, besides which there is a small amount smelted in the region, equal, for 1879, to 39,583

tons of pig iron. The shipments for 1880 are estimated at 1,950,000 tons.

§ 228. Considerable quantities of the ores from Lake Superior are smelted in or near Buffalo, at Chicago, and in parts of Wisconsin, and a much larger quantity in Ohio, where, besides those smelted in Cleveland and its vicinity, and in the Hocking Valley, the pig-iron made from these ores in the Mahoning Valley was, in 1879, 147,844 tons. The receipts of Lake Superior ores in 1880 at Cleveland amounted to 758,933 tons, and at Ashtabula to 298,594 tons, or a total of 1,057,027 tons. Of these the larger part are carried into western Pennsylvania, where they support a great iron-industry, including the Bessemer steel-works of that region. These ores seek this market because within an accessible distance from the lake-ports is to be found a cheap and excellent fuel for smelting them. The Hocking Valley, which is now rapidly increasing its shipments of coal to the lake-ports over railroads of easy grades, will, however, offer advantages equal if not greater than those of western Pennsylvania, and we may confidently expect that large quantities of the Lake Superior ores will, in a near future, find their market in the Hocking Valley, where they will vie in importance with the native ores as elements of manufacturing industry.

§ 229. The prices of the Lake Superior ores are subject to great variations, depending on the market-price of iron. In 1873 they were sold at Cleveland for $12 a ton, and in 1874 at $9; while in January, 1879, the prices for specular ores at Toledo were about $5.50 and $4.50 for Nos. 1 and 2. A year later, with the great rise in the price of iron, it is said that as much as $16 and $12 a ton were paid for these ores at Cleveland. With the depression in the price of iron, the principal mine-owners, in May, 1880, were announced as having made deductions of $2.50 and $3 per ton from the contract-prices of the No. 1 ores. The prices fixed for 1881, at

Cleveland, are, I am informed by a correspondent, $9.00 for No. 1, and $6.50 for No. 2 ore, the latter being guaranteed to yield from 55·0 to 60·0 per cent. of iron. The No. 1 ores may be said to contain from 63·0 to 66·0 per cent. of iron, being a nearly pure peroxyd, with five or six hundredths of silica. It is since announced that the Republic Mining Co. have fixed their price for No. 1 ore for 1881 at $10.00 per ton at Cleveland.

§ 230. The total iron-production of the United States in 1879 was 2,741,853 gross tons, or 3,070,875 net tons, of which latter figure Pennsylvania produced 1,607,763 tons, or more than one-half; and Ohio, the second State in iron-production, gave 447,781 tons. Mr. James M. Swank, the Secretary of the American Iron and Steel Association, to whose published report for 1879 I am indebted for these figures, and also for those relating to the imports of foreign ores, estimates, in advance of full details, the total production of pig-iron for 1880 at 3,300,000 gross tons, to which, if we add an importation of about 700,000 tons, we have for the probable consumption of pig-iron for 1880, 4,000,000 gross tons. In his tabulated results, Mr. Swank reduces the iron-production to net tons of 2,000 pounds, instead of gross tons of 2,240. It may be here noted that while the ton of castings or of bar-iron is reckoned 2,000 pounds, the ton of iron or steel rails is 2,240, and the ton of pig-iron, cast in sand, is 2,268 pounds. The ton of foreign or of Lake Superior ore is 2,240 pounds, while in Ohio the ton of native ore or of limestone is 2,268 pounds.

Our production of Bessemer-steel ingots in 1879 reached 829,439 gross tons, or about one-third that of the entire world (Great Britain producing 834,711 tons), besides 56,290 tons of open-hearth steel, and 56,180 tons of crucible steel. In 1879, we made 610,682 gross tons of steel rails, and 383,311 tons of iron rails, or a total of 993,993 tons. The estimated production for 1880, according to Mr.

Swank, is 775,000 tons of steel rail and 425,000 tons of iron rails, making 1,200,000 gross tons. In addition to these we imported about 275,000 tons of rails of all kinds, giving an approximate consumption for 1880 of 1,475,000 tons of rails. In 1879, there were laid 4,725 miles of new railroad, and in 1880, about 6,500 miles. (See Appendix, page 153.)

These figures will suffice to give some notion of the vast and rapidly increasing iron and steel-industries of the United States, in which no part of the country is more interested than the Hocking Valley, with its abundant supplies of native ore and coal, and its accessibility to the great ore-deposits of Lake Superior.

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## RAILWAY COMMUNICATIONS.

§ 231. Mention has already been made on page 92 of the railroads over which the coal of the Hocking Valley is transported. Of these, the first in time, and in importance, is the Columbus and Hocking Valley R. R., which, as already stated, was opened for traffic in 1869. The main line extends from Columbus to Athens, a distance of 76 miles, and for more than forty miles follows the valley of the Hocking River. Important branches have since been built, which are represented on the accompanying map. One of these, the Straitsville branch, leaving the main line at Logan, 50 miles from Columbus, runs north-east to Webb Station, and thence, passing the Winona, Gore and Bessie furnaces, extends to New Straitsville, a distance of 12 miles from Logan. A second, called the Monday Creek branch, leaving the main line just below Nelsonville, which is 62 miles from Columbus, runs to Bessemer, at the junction of Snow Fork with Monday Creek, and thence passing north-west, up the valley of the latter, by the station now named Mowry, (the Monday Creek station of page 93) with the Lee

furnace, by Carbon Hill, and the Crafts furnace at Greendale, meets the branch from Logan to New Straitsville about two miles west of the latter station. From Bessemer, a subordinate branch-line runs up the valley of Snow Fork, by Buchtel station, to the Helen furnace at Orbiston.

In this connection should also be mentioned the Ohio and West Virginia R. R., which connects with the C. and H. V. R. R. at Logan, and, after turning eastward, passes along the western border of the Hocking-Valley coal-field, through Starr, and the north-west corner of Brown, to McArthur (a distance of 27·5 miles), and reaches its terminus on the Ohio River, at Gallipolis, 65 miles from Columbus. This line was opened for traffic in the summer of 1880.

§ 232. The Newark, Somerset and Straitsville R. R., connecting Shawnee, in the north-west part of the field, with Newark, was opened in 1872, and is now leased by the Baltimore and Ohio R. R. Co. This company also controls the Marietta and Cincinnati R. R., which, connecting the two cities named, passes through the town of Athens, and traverses the southern part of the field, in the townships of Waterloo and Brown. A branch of this, about five miles in length, runs northward to the coal-openings at Carbondale, in the north-west corner of Waterloo. A line in continuation of this Carbondale branch was some years since projected and surveyed, which was to pass by Floodwood, and thence up Monday Creek to Bessemer, and along the valley of Snow Fork to Shawnee, the distance being 22 miles, thus affording a north and south line through the centre of the Hocking-Valley field. It is reported that the construction of this important connecting link, which is shown on the map, will not be long delayed.

§ 233. The importance of railway-communication with the eastern part of this field led, a few years since, to the construction of what was called the Atlantic and Lake Erie R. R., which was to connect Lake Erie, at Toledo, with the

Ohio River at Pomeroy. Starting from the latter point, this projected line passed northward by Athens, and, entering the Sunday Creek Valley at Salina, followed up the East Branch of Sunday Creek to Moxahala, connecting at New Lexington with the Cincinnati and Muskingum Valley R. R. The portion of this line here indicated had not been completed farther southward than the station called Corning, near the centre of the township of Monroe, when, about the beginning of 1880, the enterprise passed into the hands of the Ohio Central R. R. Co., who have already put in operation the line from Corning to Toledo, having re-laid the track with steel rails, and equipped it with the rolling-stock necessary for a large coal-trade.

§ 234. The line of the Ohio Central R. R. now passes, as we have said, from Corning, by Moxahala, to New Lexington; thence, over the C. and M. V. R. R. as far as Bremen (crossing, on the way, the N. S. and S. R. R. at Junction City), and from Bremen to Bush's station, which is 29 miles from Columbus. A branch-line of the O. C. R. R. extends thence to Columbus, which is thereby 65 miles from Corning. From Bush's, the main line of the O. C. R. R. passes to Granville, and thence, *via* Gilead, Berwick and Fostoria (at which points it connects with railroads to Cleveland and Sandusky) to Toledo.

The Ohio Central Coal Co., organized in connection with this railroad, has acquired about 12,000 acres in the northeast part of the Hocking-Valley field, chiefly in the townships of Monroe and Pleasant, and since September, 1880, has been mining and shipping large quantities of the coal of the Great Vein, which has been introduced into the market under the name of the Corning coal.

An extension of the O. C. R. R. in the Sunday Creek Valley, which should here be noticed, is to pass down the course of the projected main line from Corning to where the East Branch of Sunday Creek is joined by the West Branch,

not far from the village of Trimble; thence up the West Branch to Buckingham, and by Hemlock to Shawnee. This portion is under contract to be completed May 1, 1881. The O. C. R. R. propose, at a later day, to complete the line to Pomeroy.

§ 235. The connections of the Hocking-Valley field with the south-west are as yet incomplete. The Cincinnati and Muskingum Valley R. R., which intersects the C. and H. V. R. R. at Lancaster, 32 miles from Columbus, however, affords a communication between the coal-field and Cincinnati, making the distance from thence to Nelsonville, and to Straitsville, 155 miles. From Cincinnati, by the M. and C. R. R., the distance is about 150 miles to Carbondale, from which point a distance of four or five miles along the proposed northward extension would open a connection with the extensive mines on the Great Vein now wrought in various parts of the township of York. A new railroad from near the mouth of Monday Creek to Cincinnati is suggested, and it is said that a practical route between the two points can be found which will not differ more than ten miles from a direct line.

§ 236. Cincinnati, as is well known, gets its coal by the Ohio River, the greater part coming from western Pennsylvania; but a portion also from the Kanawha, in West Virginia, and another portion from Pomeroy in Ohio (§ 241). The price is generally low, but is subject to great fluctuations on account of the many uncertainties of the river-navigation; and in times of scarcity, Cincinnati has been forced to get considerable quantities of coal by rail from the Hocking-Valley field, as was notably the case for some months at the end of 1879 and the beginning of 1880. It is the opinion of some who have given the subject careful study, that, with better railway-facilities, the Cincinnati market can be more advantageously supplied with coal from the Hocking-Valley field than from the present sources.

§ 237. The grades on the railroads from the Hocking-Valley field to Toledo are very light, the highest on the Ohio Central R. R., which is near Bucyrus, being but 40 feet, while the highest between Columbus and Toledo is only 26 feet to the mile. The highest grade on the main line of the Columbus and Hocking Valley R. R., or on the Monday Creek branch, is 26·4 feet. There is, however, a grade of 52·8 feet on the Straitsville branch, so that coal-trains from this branch are made up at Logan. The ordinary trains from the stations on the C. and H. V. R. R. to Toledo consist of thirty cars carrying ten tons each.

We give herewith a table of distances by existing railroad lines from the principal cities above named to various points in the coal-field: —

*Distances from Chief Points to the Coal-Field.*

| | Miles. |
|---|---|
| Toledo to Columbus (C. & T. R. R.), | 123.7 |
| Sandusky to Columbus (C. S. & C. R. R.), | 123.5 |
| Cleveland to Columbus (C. C. & I. R. R.), | 138.0 |
| Toledo to Nelsonville or Straitsville, *via* Columbus, | 185.7 |
| Toledo to Shawnee (L. S. & M. S. R. R.), | 197.0 |
| Sandusky to Shawnee (B. & O. R. R.), | 159.0 |
| Cleveland to Shawnee (C. C. & I. R. R.), | 184.0 |
| Toledo to Corning (O. C. R. R.), | 181.0 |
| Cleveland to Corning (O. C. & C. C. & I. R. R.), | 189.0 |
| Cincinnati to Nelsonville or Straitsville, *via* Lancaster, | 155.0 |
| Cincinnati to Carbondale (M. & C. R. R.), about | 150.0 |

## CONCLUSIONS.

§ 238. We have in the preceding pages shown the distribution, quality and productive capacity of the various coal-seams which are found in the area of about 250 square miles, known as the Hocking-Valley coal-field, and have pointed out that, with the exception of these, and the already

partially exhausted block-coals of the Mahoning region, the western border of the great Appalachian coal-basin in Ohio yields little other than inferior and sulphurous coals. In the region between this western limit and the Mississippi, the Illinois coal-basin, which extends into western Indiana, affords also, with some local exceptions, only poor, watery, and highly sulphurous coals,* which cannot compare in quality with those of the great Eastern or Appalachian basin, though they may subserve local wants; — thus making it clear that it is to some part of this latter basin that the great States north of the Ohio River must, in the future, look for the chief part of their fuel.

§ 239. From data gathered in 1874, it appeared that of the coal received at Chicago, three-fifths, or about 960,000 tons, came from the east. Adding to this the coal received in the same year at Detroit, Cleveland, Sandusky, Toledo and Cincinnati, which was mined, with the exception of a little from the Kanawha Valley, either in Ohio or in Pennsylvania, the total was about 4,600,000 tons. Of this, some part of the 1,650,000 tons received at the three ports named on Lake Erie was re-shipped for more western stations, and would thus be reckoned twice. This amount would, however, be far more than compensated for by the internal consumption of the State of Ohio, having then a population of nearly 3,000,000, and of parts of Indiana, then receiving Ohio coals by rail, so that it was estimated that the supply of coals from the Eastern basin to the five north-western States — Ohio, Indiana, Illinois, Wisconsin and Michigan — was, in 1873, approximately 6,000,000 tons.

§ 240. The annual increase in the receipts of coal for the five years ending with 1873, at Cincinnati, Cleveland, Detroit, Chicago and Milwaukee, varied from twenty to thirty-five per cent., and averaged, for the whole, twenty-

* See on this point Macfarlane's *Coal Fields of North America*, 3d edition, pages 432–434.

five per cent. The prosperity indicated by this rapid increase was, however, temporarily checked by the commercial depression which immediately followed, and the receipts of coal, both at Cincinnati and Cleveland, during the next few years, showed a marked falling-off, which was not fully made up before 1879. Chicago, however, during these six years, showed a gradual increase from 1,668,257 tons in 1873 to not less than 2,384,974 tons, and for the first nine months of 1880, received 1,949,825 tons, being an excess of 264,286 tons over the receipts for the same period in 1879. Of this, 562,606 tons were anthracite, of which 311,980 tons, together with 211,472 tons of bituminous coal, came by the lake. The remaining anthracite, with 1,176,347 tons of bituminous coal (with which coke is included) were received by rail; but the report of the Secretary of the Board of Trade of Chicago gives no data from which we can determine what proportion of this last comes from the Western and what from the Eastern coal-basin.

§ 241. The entire amount of coal received at Cincinnati for the season 1878–79 was 1,368,426 tons, or within a small fraction the same as six years previous. Of this, 830,761 tons were from western Pennsylvania, 253,361 tons from the Kanawha, in West Virginia, and only 253,544 tons from Ohio, being chiefly by the river, from Pomeroy, with a small amount of Hocking-Valley coal by rail. There were, in addition, 30,750 tons of anthracite; besides which, in 1879, Milwaukee received 111,545 tons, Chicago 464,360, and Cleveland 76,187 tons, making a total of 682,842 tons of anthracite. Of that received at Cleveland, 63,386 tons came by rail; and we have already seen that nearly one-half of the anthracite arriving at Chicago in the first nine months of 1880 also came by rail — a fact which is due to the cheapness of westward freights, and is of great significance as regards the supply of the western markets with coal by rail direct from the Hocking Valley. A con-

siderable trade of this kind has been for several years successfully carried on from Columbus to Chicago.

§ 242. We have now before us some data from which to arrive at an approximate estimate of the amount of coal received by the north-western States from the Eastern basin in 1879. If we add to the 783,142 tons of anthracite, the 1,084,122 tons of bituminous coal from Pennsylvania and West Virginia received at Cincinnati, we have 1,766,864 tons. The amounts of Pennsylvania anthracite, coke and bituminous coals which find their way westward to other points within our area than those already mentioned, are considerable, and would probably augment the sum to 2,000,000 tons. To this must be added the entire out-put of the Ohio mines, which for 1879 is, by the State Inspector of Mines, estimated at 5,000,000 tons, making the supply of coal from the Eastern basin to the north-western States, Ohio included, equal to 7,000,000 tons for 1879. But, according to the same authority, Ohio alone will produce 7,000,000 tons of coal in 1880 (§ 171), so that the total supply will be between 9,000,000 and 10,000,000 tons in 1880, and not far from 11,000,000 tons in 1881.

§ 243. The country having happily recovered from the long financial depression of 1873–78, and entered once more in the way of prosperity, we may fairly expect that the increase of its various industries, and its growing internal commerce, will create once more, as in the years before 1873, a rapidly augumenting demand for coal. The two States of Ohio and Michigan have, by the census of 1880, respectively about 3,100,000 and 1,600,000 souls; and within the past decade have increased, the former 16·3 and the latter 35·0 per cent. in population; while the five north-western States which are in great measure dependent for their fuel-supply upon the Eastern basin, have, according to the same census, an aggregate population of 11,186,500, and have, during the last ten years,

increased, as a whole, 22·5 per cent. In these calculations we have not taken into account Iowa, Minnesota, and other north-western regions, which must also look to the East for their fuel.

To this we must add the province of Ontario, now with a population of 1,800,000, which is also dependent for its coal-supply upon the Eastern basin, and, owing to the facilities offered by the lake-navigation, gets a considerable part of its coal from the Mahoning and Hocking valleys. The coal imported into Ontario in 1880 amounted to 748,771 tons, of which a little over one-half was bituminous. The increase in the amount in the two years from 1878 to 1880 was 27·0 per cent.

§ 244. From what sources is this great population to be supplied with fuel in the years to come? The Illinois or Western coal-basin, notwithstanding the inferior quality of most of its coals, will doubtless continue to supply many local wants, and Pennsylvania, as hitherto, will furnish a considerable share. It is, however, to Ohio, from its geographical position, and from the natural course of trade, that we must look for an increasing proportion of the supply; and, for reasons already given, it is more especially to the Hocking Valley that a great portion of the North and West must draw the principal part of its coal for generations to come; while if, as is maintained (§ 236), the Cincinnati market can be advantageously supplied from the same source, another important demand upon this region will be established.

§ 245. It has been farther shown in the preceding pages that within the Hocking-Valley coal-field, and along its western border, there is found a large supply of iron-ores of various grades and kinds, with which there has been built up within the last six years an iron-industry already nearly equal in production to that of the Hanging-Rock region. In addition to this, the geographical position of the Hocking

Valley, its abundant coal, and the large shipments of this to the lake-ports, unite to make it a point to which a great proportion of the iron-ores of Lake Superior should come for treatment. The distances from Toledo and Sandusky to the Hocking-Valley coal-field, over roads of easy grade, exceed but little that from Cleveland to Pittsburgh; and it is to this region of superior and abundant fuel, that Ohio and more western States may naturally look for a large part of their future supplies of iron and steel.

§ 246. In view of all these considerations, I cannot better sum up the advantages presented by the Hocking-Valley coal-field than by reprinting, with a few verbal changes, the concluding paragraphs of my report of May, 1874 on this region: —

"The bituminous coal of south-eastern Ohio, may, in its geographical, commercial and industrial relations, be compared to the anthracite of Pennsylvania. The latter, occupying an area of about four hundred and seventy square miles, placed on the eastern border of the broad Appalachian basin, has before it to the north and east the rich and populous, but coalless States of New York and New Jersey, with those of New England, which look to it for their chief supply of fuel. Moreover, in New York, in New Jersey, and in eastern Pennsylvania are immense deposits of rich iron-ores, which find in the anthracite the fuel necessary for their reduction and manufacture."

"If now we turn to the west, we find on the opposite border of the Appalachian basin the coal-region of eastern Ohio, and particularly the Hocking-Valley coal-field, with its two hundred and fifty square miles of superior and easily mined coal, sustaining similar relations to the rich and populous States to the north and west, which must, in time to come, look to it for the supply of a great portion of their fuel. In addition to this, we have, as a further resemblance,

the vast amounts of iron-ores, not only those of southern Ohio itself, but those of Lake Superior, which, with the rapidly increasing export-trade in coal from this region, will find their way thither in larger quantities, to be smelted and manufactured. In view of all these facts, we may with confidence expect to see this coal-field, and its vicinity, the seat of a metallurgical industry comparable to that of the Lehigh Valley, and of Pittsburgh."

# APPENDIX.

## FIRE-CLAY AND OTHER CLAYS.

§ 247. Refractory clays suitable for the manufacture of fire-brick are not infrequent in the coal-measures, and important deposits are found at their base, near Sciotoville and Webster, in Scioto County, where fire-bricks are made on a large scale. Farther northward, also, in Tuscarawas County, similar fire-clays are mined at a higher horizon in the coal-measures. Clays from both of these counties have been analyzed by Dr. Wormley for the Geological Survey of Ohio. Little information is however given in the reports of the survey respecting similar clays in the Hocking Valley. A non-plastic clay of good quality is mined near Logan, and is said by Orton to lie immediately above the Maxville limestone (to which horizon also he also refers the Scioto County clays), and is used for the manufacture of fire-brick at Columbus (page 43). I have observed a bed of white non-plastic clay ten or twelve feet in thickness in section 33 of Ward, which was a little above what was regarded as the Shawnee limestone (page 53). Prof. Read mentions also having received a similar clay, apparently of good quality, from a locality not seen by him, in the north-east corner of Ward. As already mentioned, three or four feet of a non-plastic clay underlie the Helen black-band ore, in the south-east part of Ward. Specimens of this clay were found to burn white, and the deposit may be found of value.

Read farther mentions the existence of a clay at Haydenville which is mined for the Columbus potteries (page 45).

A white plastic clay underlies Coal V, near Nelsonville, and clays, said by Andrews to be between Coals V and VI, are, according to him, largely used for the manufacture of pottery in some parts of Perry and Muskingum counties. These various deposits of clay in the Hocking Valley deserve, and will doubtless receive farther examination.

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## SALT-WELLS AND SALT-MAKING.

§ 248. It is well known that brines are found over a large area in south-eastern Ohio, where they have for many years been utilized for the manufacture of salt, chiefly in Meigs County, on the Ohio River. There are, however, salt-wells in Athens, Perry, Muskingum and Tuscarawas counties. The seat of these brines is in the upper part of the Waverley sandstone, which immediately underlies the coal-measures, and at Pomeroy, in Meigs County, the wells are bored 1,000 feet, through the whole of the lower coal-measures. To the north-west, the depth of the wells of course decreases, and in the Hocking Valley it is little over one-half of this. In a well at Salina, already noticed (page 53), which is 600 feet deep, the salt-water was said to have been reached at 560 feet. The name of Salt Lick township comes from its salt-springs, and salt has been, and perhaps is still made, from brines got by boring at McCuneville in that township.

§ 249. Salt-wells exist in Dover, at Chauncey and at Salina, the latter of which were in partial activity when I visited the locality in May, 1880. There are six wells, of which only two were then pumped. I was told that the whole number would yield brine enough to make 150 barrels of salt daily. I have found no analyses of these brines, or determinations of their density, but was told by the manager at Salina that the brine yielded 10·0 per cent. of salt, which would be equal to a bushel of 56 pounds of salt to about 63

gallons or two barrels of water. The weakness of this brine, as compared with that of some other salt-regions, is compensated for by the cheapness of fuel, the slack or waste coal from the mining of the Great Vein being here employed to effect the evaporation of the brine. I was told by the proprietor that the cost of making salt at Salina in 1878 was sixty cents the barrel.

The mother-liquor or bittern from the brines at Salina, as elsewhere in this region, yields a considerable amount of bromine, and works for its separation were in operation there at the time of my visit.

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### INCLINATION OF THE COAL.

§ 250. The inclination to the horizon of the strata of the Hocking-Valley coal-field, as determined by that of the Great Vein, or Coal VI, is a point of much interest, which demands a careful discussion. The elevation of this seam above Lake Erie at various points, as determined by Mr. C. H. Jennings and others, furnished Col. Charles Whittlesey with data from which, in 1873, he calculated the direction of its dip to be from about 62° to 79° east of south, with an inclination varying from about twenty feet in a mile in the northern portions, to twenty-four, twenty-five, and thirty feet in the more central portions, and from thirty-two to thirty-six feet in the southern parts of the coal-field.

These results, with some farther details, were embodied in my report in 1874, and the fact was pointed out that the rate of dip increases towards the southern part of the field, where, however, some doubt existed as to the identification of Coal VI.

§ 251. In volume III. of the Geological Survey of Ohio, page 703, Prof. M. C. Read has calculated the inclination from the elevations fixed by Messrs. W. H. Jennings and I.

B. Riley for various outcrops of the Great Vein in the more northern parts of the field, in Green, Ward and Trimble. The inclination for the longer sections was found to be from twenty-five to twenty-eight feet to the mile; but the fact was brought out that there are small undulations, resulting in local variations in the rate of dip. Thus, from south-eastern Green to south-eastern Trimble, while the average dip for the eleven miles was 27·45 feet to the mile, that of certain portions varied from 23·00 to 34·66 feet.

§ 252. The strike of the coal was by Read determined by taking distant points at which the Great Vein is found at the same elevation above Lake Erie (the datum line). Thus, both in section 7 of Ward, and at Ferrara, on the north limit of section 22 of Monroe, this coal-seam is found at 167 feet above the lake. The bearing of the line of ten miles, connecting these two points, which we will designate as A — B, is N. 32° E., and the dip, at right angles to this line of strike, is consequently S. 57° E.

In the north part of section 19 of Ward, and again near the centre of section 32 of Pleasant, the Great Vein is 231 feet above the lake. The bearing of this line of thirteen and a quarter miles, which we shall call C — D, is N. 26° E., giving a dip of S. 64° E.

Near the centre of section 32 of Ward, and again in the south-west part of section 26 of Pleasant, the elevation of the Great Vein is 270 feet, and the connecting line, E — F, of fourteen and a quarter miles, had a direction N. 22° E., giving a dip of S. 68° E.

§ 253. It will be notices, says Prof. Read, that, to the eastward, the line of strike makes a greater angle with the meridian than at the more western outcrops: the line A — B being the most eastern, and E — F the most western of the three just indicated. This is farther apparent if we connect an outcrop of the Great Vein on the southern border of section 11 of Ward, where the elevation is 113 feet, with

another very nearly at the same elevation, or 110 feet, in the north-east corner of section 11 of Trimble. This line, which we will call G — H, and which is to the eastward of A — B, is nine and a half miles in length, and has a direction N. 42° E., or, making ample allowance for the correction due to the somewhat lower level of the northern outcrop, N. 40° E., giving for the direction of the dip, S. 50° E.; that of the three lines previously indicated to the west of this being successively S. 57°, 64°, and 68° E.

§ 254. As regards the rate of inclination, the map of the Hocking-Valley region, published by Mr. Jennings in 1878, gives data from which we have been enabled to make farther determinations for the Great Vein, especially in the portions of the field both to north and south of the townships of Green, Ward and Trimble, in which Prof. Read's observations were made.

Taking as a basis the most western line of Prof. Read, E — F, corresponding to an elevation of 270 feet for the Great Vein, the distance therefrom, in the direction of the dip, to the outcrop at 231, feet already mentioned in the middle of section 32 of Pleasant, is two and five-eighths miles, which, neglecting fractions, gives a descent of fifteen feet to the mile. From the same line, E — F, to the outcrop at 167 feet near Corning, a distance of six miles S. 68° E., the descent is seventeen feet to the mile. From the same to the outcrop at 110 feet, already mentioned, in the north-east corner of Trimble, — a distance of eight and a quarter miles S. 68° E.,—the descent is at the rate of nineteen feet to the mile.

§ 255. Proceeding southward in the field, the Great Vein is seen in the south-west quarter of section 32 of Coal township, at a point less than a mile west of the line E — F, and at an elevation of 284 feet. From this point, at right angles to the line, to a boring in fraction 36 of Trimble, where the Great Vein is twenty-four feet above Lake Erie,

a distance of eight and a half miles S. 63° E., the dip is thirty feet to the mile.

From the same line, E — F, to the outcrop in section 7 of Ward, where the elevation of the Great Vein is 167 feet, — a distance of four miles S. 68° E., — the descent is twenty-five and three-quarters, or nearly twenty-six feet to the mile; and along the same line of dip, eastward to the line of strike G — H, in the north-east corner of York, — a total length of six and one-eighth miles, — it is still twenty-six feet to the mile.

§ 256. In the south-western part of Ward, from the line E — F, at a point near the outcrop of 270 feet elevation in section 32, a line S. 68° E. to the outcrop of 231 feet, measures two miles, making the descent less than twenty feet to the mile. From the outcrop of 270 feet just mentioned, to that of 113 feet in the southern part of section 11 of York, a line of five and seven-tenths miles (nearly in the direction of dip indicated by the line G — H), gives a descent of twenty-seven and a half feet to the mile; while a line S. 68° E. from E — F to the outcrop of 113 feet, measures five and a half miles, and gives a descent of twenty-eight and a half feet to the mile. The mean of these two, or twenty-eight feet, may be assumed as the rate of dip of the Great Vein in this part of the field.

§ 257. More than two miles west of the southern prolongation of E — F, at Haydenville, in section 13 of Green, the Great Vein is 317 feet above the lake, and in a shaft near the village of Chauncey, in section 20 of Dover, it is fifteen feet below the same level. The distance between these two points being twelve miles, we have a descent, for the whole distance, of 332 feet, or twenty-seven and seven-tenths feet to the mile. The line connecting these two points is very nearly at right angles with the southward prolongation of E — F, and less than a quarter of a mile south of the line, in section 35 of York, is an opening where the Great

Vein is seen at 242 feet. The descent from Haydenville to this point, three and four-tenths miles, is at a rate of twenty-two feet, and for the remaining distance is a little over thirty feet to the mile.

§ 258. From the opening just noticed in section 35 of York to Hamley's Run, in the south-west corner of section 32 of Dover, where the Great Vein is mined at twenty-nine feet above the lake, is a distance of six and eight-tenths miles S. 57° E., very nearly, which corresponds to the line of strike A — B, which is that of the outcrop of 167 feet. The descent in this interval is equal to a very little over thirty feet to the mile.

Another line from an opening where the Great Vein is seen at 238 feet, in the north-western corner of section 34 of York, in a direction S. 67° E., seven miles to the Great Vein, at Hamley's Run, gives also a dip of thirty feet to the mile.

A line connecting the outcrop of the Great Vein at Haydenville with Hamley's Run, a distance of ten and a half miles S. 61° E., gives an average inclination of twenty-seven and four-tenths feet to the mile. If, however, we divide this line into two parts, we find for the first four and seven-tenths miles, from Haydenville to the line of outcrop of 242 feet elevation, a descent of only twenty-two feet, while for the remaining distance to Hamley's Run it is thirty feet.

Still another line from the outcrop of 238 feet, in section 34 of York, to the town of Athens, where the Great Vein is 118 feet below the level of Lake Erie, gave for a measured line of eleven and one-half miles S. 55° E., a dip of a small fraction over thirty feet to the mile.

§ 259. The determinations just given, having shown that the descent of the Great Vein from the outcrops in sections 34 and 35 of York to Chauncey and Hamley's Run, is at the rate of thirty feet to the mile, we may, assuming this to be

regular, calculate the elevation at which the Great Vein should be found along the lines connecting the points named. The line C — D, of 231 feet elevation, would pass, as might be expected, a little distance east of the outcrop of 234 feet in the north-west corner of section 34 of York. The line A — B, of 167 feet, will pass towards the north-east corner of section 26 of York, while that G — H, of 113 feet, should pass through the eastern half of fraction 7 of York.

These lines, and especially A — B and C — D, are seen to be continued, with scarcely any deflection, for distances of fifteen and seventeen miles, and permit us, with a strong degree of probability, to conclude as to their courses for distances of six or eight miles farther. We find that the course of the line of 113 feet would take it very close to Mineral City, in Waterloo, where the elevation of the railroad is 153 feet, and that of the coal there mined, 155 feet, above Lake Erie; thus affording a strong presumption that the Mineral City coal is really a higher seam than the Great Vein. In like manner the line of 167 feet, A — B, would pass near Moonville station, which is 150 feet above the level of Lake Erie.

§ 260. We have seen that along the western border of the field, in south-eastern Ward, the rate of descent for two miles is only twenty feet; and again, that in the section from Haydenville, for a distance of over three miles towards the south-east, the inclination is but twenty-two feet to the mile. Thus the western border of the field, to the southward, preserves the gentler rate of inclination which we have found to prevail along this border farther to the northward. As a consequence of this the Great Vein in the southern part of the field should extend much farther to the westward than if its rise were at the hitherto supposed rate of thirty feet to the mile, which prevails a little farther to the east.

§ 261. As an aid to farther inquiry, we may here note that according to Prof. Orton, Coal VI is met with on the

land of Mr. Chichester, in section 35 of Starr, where however, as elsewhere along the western border of the field, its thickness is little over four feet. (§ 12, 13.) Prof. Orton also informs me that the same coal-seam is found in the tops of the hills as far west as Ilesboro', near the centre of Washington township.

The following are the elevations above Lake Erie of some points on the line of the Ohio and West Virginia R. R., along the western border of the Hocking-Valley coal-field, for which I am indebted to the courtesy of Mr. F. B. Sheldon, the engineer of the Columbus and Toledo R. R.: Junction of the O. and W. Va. R. R. with the C. and H. V. R. R., near Logan, 148 feet; New Cadiz, 168; Union furnace, 183; N. E. corner of fraction 32 of Starr, 324; Starr station, 205; crossing of boundary between Starr and Brown townships, 207; Swan station, 138; Creola (late Karnsgrove) station, 160; section 10 of Elk township, 215; McArthur, 163, and intersection with the Marietta and Cincinnati R. R., 171 feet.

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## PRODUCTION OF BESSEMER STEEL IN 1880.

Since pages 132 and 133 of this volume were in print, Mr. Swank, the Secretary of the American Iron and Steel Association, has published the official returns from the eleven Bessemer Steel-works of the United States, for the calendar year, 1880. These returns show a production of not less than 1,074,262 gross tons of Bessemer Steel ingots, being an increase of 244,823 tons, or more than 29 per cent. over that of 1879. The production of steel rails in 1880, reached 819,729 gross tons, thus exceeding by about 45,000 tons the estimate previously given.

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